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April 1995

Sustaining Ecosystems

A Conceptual Framework

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Version 1.0

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Table of Contents

List of Tables

List of Figures

Preface

This Conceptual Framework provides an analysis process to be used as a step in implementing ecosystem management within the Pacific Southwest Region. It incorporates current ecosystem theory with existing efforts within the Forest Service to classify and describe ecosystems. Adopting the process outlined in this Conceptual Framework and working to further its evolution will result in a fundamental change in how Region 5 accomplishes land management. The document represents a turning point for the Region by providing a foundation for ecosystem management. The Conceptual Framework fulfills a four-part purpose:

- To provide scientific underpinning for our approach to sustaining biodiversity and ecological systems;
- To outline a process that enhances the use of scientific information in analyses, planning, and decision-making;
- To describe a means of measuring our progress in achieving the objectives of ecosystem management; and
- To address how we can achieve ecosystem management objectives by increasing collaboration with publics, other agencies, academia, and local communities.

The Conceptual Framework correlates well with thoughts expressed by Forest Service Chief, Jack Ward Thomas (Thomas 1993):

> "It is time to consider land use in a broader context than a series of single-use allocations to address specific problems or pacify the most vocal constituencies. We cannot continue along our present path of dealing with the assured welfare of individual species as constraints and outputs of goods and services as objectives. The questions are bigger and more complex. We stand on shaky ground and must either step back from the commitments in the Endangered Species Act, National Environmental Policy Act, and National Forest Management Act or move on to an expanded concept more in keeping with current scientific thinking and capability and developing societal values and demands. Such an approach will require consideration of the conservation of ecosystems and their processes at the landscape level. This new approach would identify forest sustainability for recognized values and uses as the foremost goal of National Forest management and use the conservation of biodiversity as a mechanism to that end. We must learn to prevent the creation of threatened species rather than performing heroic management feats to pull species back from the brink of extinction."

Our attitude toward change is of critical importance. Successfully adopting the process presented in the Conceptual Framework and using it as a building block for the Region's future will require the support of each employee.

The Conceptual Framework is not the final word. Much work lies ahead in refining the path the Region has chosen. In addition to applying current techniques, we will continue to invest in research and development. Developmental efforts further our knowledge, fill information gaps, and improve the quality of and access to resource data.

We are striving for:

- A work force of resource professionals with the skills needed to apply technical scientific information and tools to land management, as described in the Conceptual Framework;

- An organization that speaks with one voice about our mission and vision for the future, which will increase our success in collaborative decision building and improve employee morale; and

- The ability to clearly understand and accept our capabilities and limitations in producing desired outcomes, thereby increasing our credibility with the public.

Acknowledgments

In March of 1993, the Ecosystem Management Steering Committee for Region 5 commissioned an effort to define ecosystem management objectives for the Region and incorporate them into planning. Patricia Manley (Team Leader) and Phil Aune (Pacific Southwest Station Liaison) were chosen to initiate and guide the effort. They formed a team consisting of resource experts in various fields.

Specifically, the team was charged with 1) developing clear objectives for ecosystem management in the Region; 2) defining major ecosystems in the Region and specifying the scale at which they operate, defining their basic components and functions, and developing measures and thresholds of functionality and integrity; and 3) developing a process by which these objectives can be incorporated into planning (i.e., project, Forest, multi-Forest). The product of this effort is this document, "Sustaining Ecosystems: A Conceptual Framework", and its supplemental materials. This document was first issued as a draft consisting of a three volume set (Draft Region 5 Ecosystem Management Guidebook) in February of 1994. The team members responsible for developing this document are listed below.

Patricia N. Manley	Team leader, Regional Wildlife Ecologist, Regional Office, San Francisco
Gary E. Brogan	Regional Landscape Architect, Regional Office, San Francisco
Carolyn A. Cook	Hydrologist, Lower Trinity Ranger District, Six Rivers National Forest, Willow Creek
Mary E. Flores	Wildlife Biologist, Warner Mountain Ranger District, Modoc National Forest, Cedarville
Donald G. Fullmer	Forest Silviculturist, Sequoia National Forest, Porterville
Susan J. Husari	Assistant Director of Fire and Aviation Management, Regional Office, San Francisco
Thomas M. Jimerson	Ecologist, Six Rivers National Forest, Eureka
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Michael E. McCain	Fisheries Biologist, Smith River National Recreation Area, Six Rivers National Forest, Gasquet
Judy A. Rose	Historic Preservation Officer, Regional Office, San Francisco
Gary J. Schmitt	Soil Scientist, Sierra National Forest, Clovis
John C. Schuyler	Forest Planner, Inyo National Forest, Bishop
Michael J. Skinner	Economist, Regional Office, San Francisco

In addition to formal team members, a number of individuals contributed significantly to the effort. They are listed in alphabetical order:

Phil Aune	Team liaison with Pacific Southwest Station and Regional Ecosystem Management Steering Committee. Program Manager, Pacific Southwest Station, Redding
Wendy Bertrand	Communication Consultant for the team. Facility Planner (retired), Regional Architect, Regional Office, San Francisco
Jean Ann Carroll	Cartographer for the team. Supervisory Cartographer, Geometronics, San Francisco
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Wendy Shaul	Format Editor for the team. Visual Information Specialist, Georgetown Ranger District, Eldorado National Forest, Georgetown
Sonia Tamez	Special Consultant to the team. Community Forestry and Tribal Government Program Manager, Regional Office, San Francisco
Carmen White	Special Consultant to the team. Public Affairs Specialist, Regional Office, San Francisco
Wally Woolfenden	Special Consultant to the team. Historical Ecologist, Mono Lake Ranger District, Inyo National Forest, Lee Vining

Numerous individuals from various agencies contributed their expertise in all areas of land and resource management. Their contributions were invaluable and are noted in greater detail below.

We were greatly assisted by our facilitators. They were Kathy Harcksen (Forester, Pacific Southwest Station, Redding), Allen King (Forest Geologist, Plumas NF), Val Russell (Civil Engineering Technician, RO), Wendy Rook (Management Analyst, RO), and Joe Oden (Planner, LTBMU).

In the formative stages of the effort, representatives from many agencies participated in team meetings and contributed to the formation of ideas and their applications, particularly in regard to biological diversity and sustainability. Participating agencies included the California Department of Fish and Game (Marc Hoshovsky, Tim Burton), California Department of Forestry and Fire Protection (Greg Greenwood, Marty Berbach), Bureau of Land Management (Carl Roundtree, John Willoughby), North Coast Water Quality Board (Chris Knopp), and California State University, Sacramento (Mark Nechodom).

We are grateful to a large cast of talented and supportive scientists from Universities (California, Washington, and Pennsylvania) and agency personnel for providing in-depth reviews of papers in progress. They included professors from Humboldt State University (Jerry Allen, Dale Thornburgh, John Sawyer), U.C. Berkeley (Larry Davis), U.C. Davis (Dennis Pendleton), Cal Poly San Luis Obispo (Ron Taskey), Penn State University (Alan Taylor), University of Washington (Jim Agee), and National Biological Survey (Dave Graber).

The Intermountain, Pacific Southwest, and Northwest Stations contributed significantly to all aspects of the effort. Barbara Weber and Garland Mason helped the team tremendously by being true advocates for the effort. In addition, many scientists contributed their expertise by participating in early meetings, providing valuable feedback on ideas, and reviewing lengthy literature reviews and white papers (Steve Arno, Connie Millar, Jim Laacke, Bill Laudenslayer, Bret Harvey, Kevin McKelvey, Bill Oliver, Phil Weatherspoon, Carl Skinner, Jared Verner, Kathleen Mathews, Rowan Rowntree, Bruce Marcot, Sue Conard). In addition, the staff at Pacific Southwest Station-INFO in Albany were very helpful; their assistance in securing documents in a thorough and prompt manner was of great help to the team.

Many individuals within the Region contributed to the effort. The Ecosystem Management Steering Committee, in particular Ed Whitmore, Katherine Clement and Sylvia Arbelbide, provided invaluable guidance and support throughout the effort. Numerous resource professionals, including ecologists, biologists, soil scientists, geologists, and air resource specialists throughout the Region contributed significant amounts of time to developing an in-depth description of components of terrestrial ecosystems on Forest Service lands in California. A number of other individuals in the Region attended meetings, gave presentations to brief the team on various ecosystem management activities occurring in the Region, worked directly with team members at meetings, or provided in-depth reviews of papers in progress. Thanks to Suraj Ahuja, Leigh Beck, Joelle Buffa, Nelly Chan, Carlos Davidson, Lynn Decker, Jack Gipsman, Chuck Goudey, Harley Greiman, Lydia Grimm, Polly Hays, Jon Kennedy, Mike Landram, Al Olson, Henry Paaso, David Solis, Richard Spradling, Rich Svilich, Tina Terrell, Ed Toth, Ralph Warbington, John Wenz, and Jerry Williams for investing time in educating and working with the team.

Thanks to the Six Rivers, Shasta-Trinity, and Eldorado National Forests, the Lake Tahoe Basin Management Unit, Pleasant Hill Engineering Center, Northern California Service Center, Pacific Southwest Station-Redding, and the Regional Office for hosting meetings.

Unfortunately, it is impossible to recognize everyone who contributed to the effort. We received input, suggestions, ideas, information, written material and help from well over a hundred other employees within the Region, all of them helping to clarify and improve this document. It is gratifying to find that the Pacific Southwest Region has so many individuals willing to contribute unconditionally to efforts to move the Region forward. The promise of contributing to fundamental change and the tremendous support within the Region made the long hours, travel, and added stress experienced by the team seem like a small price to pay for progress. A final thank you to everyone that helped make Region 5's "Sustaining Ecosytems: A Conceptual Framework" come to fruition.

Executive Summary

The USDA Forest Service committed to a management philosophy called "ecosystem management" in June of 1992. Ecosystem management is a term created to distinguish that the ecosystem itself is the context for management rather than just its individual parts. Objectives for ecosystem management include sustaining the diversity and productivity of ecosystems.

Sustaining Ecosystems: A Conceptual Framework, has been developed to guide implementation of ecosystem management in the Pacific Southwest Region of the Forest Service. The Framework addresses three major areas: scientific concepts and principles of ecosystem management, the analysis and planning process, and some methods and considerations for implementation. This Executive Summary provides a basic overview of the concepts and approach developed in the Conceptual Framework.

The ecosystem management approach presented is designed for systems where the organisms within the ecosystem are generally similar to what have been there for a long time.

What is an ecosystem

Ecosystem - A system formed by the interaction of living organisms (including people) with their environment.

The Conceptual Framework views ecosystems as encompassing physical, biological, and cultural/ social dimensions (Figure 1).

An ecosystem may be described within the gut of a termite or encompassing the entire planet (or any level in between). Thus, ecosystems are nested within larger ecosystems in a hierarchy of scales.

Ecosystem boundaries are devised by humans to meet our needs for analysis and understanding. The scale and boundaries selected depend on the problem or question being addressed. The Forest Service will ordinarily consider relatively large landscapes, on the order of watershed size or larger, for analysis.

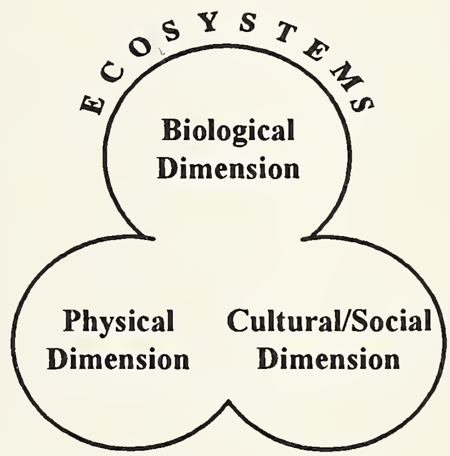

Figure 1. Three dimensions of ecosystems.

When one considers the entire array of organisms and all of their interactions with other organisms and their physical environment, it is apparent that the ecosystems we manage are tremendously complex. In order to simplify and organize this complexity, we characterize all ecosystems by fundamental *elements* consisting of components, structures, and processes.

- *Components* are the kinds and numbers of organisms and physical attributes that make up the ecosystem—the "pieces" (e.g., water, plant species, soil particles, people).
- *Structures* refer to spatial distributions or patterns (vertical and/or horizontal) of these "pieces" (e.g., streams and lakes, vegetation mosaics, characteristic soil particle configurations, towns and cities).

- *Processes* refer to the flow or cycling of energy, materials, and nutrients through space and time (e.g., flow and channeling of water, photosynthesis, plant uptake of water and nutrients from the soil, exchange of goods through trade networks).

Whether we recognize it or not, changes are taking place constantly in ecosystems. Physical, biological, and cultural/social processes are constantly at work, altering the components, structures, and processes at specific sites and across landscapes. Simultaneous changes that occur through succession, disturbance, and analogous cultural/social phenomena create diversity in the landscape spatially and temporally.

What is ecosystem management?

Ecosystem Management - The skillful, integrated use of ecological knowledge at various scales to produce desired resource values, products, services and conditions in ways that also sustain the diversity and productivity of ecosystems.

Ecosystem management is the means the Forest Service will use to meet goals specified in agency programs and plans. It is the means to an end, not an end in itself. In application, we must recognize that ecosystem management will not work unless resulting actions are scientifically credible, legally defensible, and socially acceptable.

The Conceptual Framework deals with five basic questions:

1) How did ecosystems evolve?
2) What is sustainable?
3) What do we want?
4) What do we have?
5) How do we move conditions from what we have to what we want?

The first three questions are critical in shaping our approach to planning and resource management. They change the focus from *output* driven project planning including, "What do we need to mitigate?", as done in the past, to *outcome* driven planning asking, "What conditions do we want to create?", as practiced in ecosystem management. Answers to the third and fourth questions help us to decide if there is a present need for management actions at all. Alternative solutions to the fifth question provide the means for project design and execution.

How did ecosystems evolve?

An understanding of ecosystems, and how they developed and evolved to their present states, is necessary if the ecosystem itself is to be the context for management actions. Understanding the adaptations of organisms and cultures to their environment is critical to successfully manage for conditions we wish to create.

What is sustainable?

Sustainable Ecosystem Management - Management directed towards developing or maintaining a synergistic complex of plants, animals, and cultural components which can be perpetuated indefinitely.

Forest Service policy on ecosystem management includes an objective to manage for "sustainable ecosystems"—to retain their integrity in terms of components, structures, and processes. Biodiversity is defined as the variety of organisms, their interconnections, and their associated ecological processes. Similarly, cultural diversity is important to the stability of the cultural/social dimension of the ecosystem. Both biodiversity and cultural diversity represent the integrity of an ecosystem. The more integrity can be maintained, the lower the risk to sustainability of the ecosystem.

The Conceptual Framework recommends the use of an ecocentric, coarse filter biodiversity conservation approach combined with biocentric, fine filter

approaches.[1] This means providing conditions within and across landscapes that mimic those that have occurred over evolutionary time scales (thousands of years). Because landscape conditions are dynamic in space and time, conditions designed to ensure sustainability will mirror variation produced in nature. This variation is called the *Reference Variability* (this has also been referred to as the natural range of variability or range of historic variability).

Reference Variability - The distribution of data values for an environmental indicator over a selected period of time (for biological indicators, an evolutionary time period).

Restoring and maintaining landscape conditions within distributions that organisms have adapted to over evolutionary time is the management approach most likely to produce sustainable ecosystems.

Reference Variability also applies to cultural/social elements. Conservation of cultural diversity is important to the stability and adaptive capabilities of the cultural/social dimension of our ecosystems. The time scales selected for analysis of these variabilities must be appropriate for the element considered. Cultural elements may be analyzed using both open and closed-system methods. Open-system analysis recognizes all of the interactions with other elements. The closed-system approach focuses on preservation of a particular element.

We assume that management designed to maintain or reproduce key components, structures, and processes is the management approach most likely to sustain ecosystem integrity and productivity. Conceptually, this is done by following three general steps:

1) Determine what ecosystem elements (components, structures, processes) are key for a particular ecosystem.
2) Identify measurable environmental indicators for the key ecosystem elements. These indicators measure the key elements (directly or indirectly) which in turn reflect ecosystem integrity.
3) Manage within Reference Variabilities for these indicators (additional constraints on management may be prudent in actual management planning, see next section).

Under this management approach, ecosystem sustainability and conservation of diversity depend on managing environmental indicators within Reference Variabilities.

What do we want?

Desired Condition - A portrayal of land or resource conditions which are expected to result if planning goals and objectives are fully achieved.

Ecosystem Management philosophy emphasizes the identification of *desired condition*. Desired condition reflects a combination of physical, biological, and cultural/social considerations. It expresses conditions or states we would like now and into the future. Although many conditions may potentially be sustainable, management for sustainable ecosystems may best be achieved, as discussed previously, by actions designed to produce conditions where environmental indicators are within Reference Variabilities.[2] Reference Variabilities should be used as benchmarks related to sustainability of the ecosystem.

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[1] The coarse filter approach is used in conjunction with the established biocentric, fine filter approach in a combined conservation management strategy. The fine filter process will continue to provide for at risk species and will monitor effectiveness of the coarse filter approach.

[2] There will be instances where management within all Reference Variabilities is not feasible and/or desirable due to past influences or conflicting Reference Variabilities (e.g., biophysical variabilities that are exclusive of cultural/social variabilities). In such cases, analysis and justification of why the selected desired condition is sustainable and desirable would be necessary.

Reference Variabilities represent the full distribution of values for environmental indicators including infrequent and extreme events (e.g., severe floods, high intensity wildfires, etc.). The role of these more extreme disturbances in maintaining ecosystem processes is not well understood, but their importance for biological elements is a well-accepted notion. It is unlikely that management activities can substantially prevent such events from occurring. If we chose to replicate such major disturbance events through management, and they occur anyway, we run a greater risk of disrupting the integrity of the ecosystem. It is therefore prudent to manage within a subset of Reference Variabilities referred to as *Recommended Management Variabilities* (this has also been referred to as recommended management ranges).

If we had complete, long-term data for a particular indicator, the Reference Variability could be displayed by graphing values by frequency.

It would likely appear as a bell or inverse "J" shaped distribution (Figure 2). The entire Reference Variability distribution is important and should be realized, for biological elements, over long-term, evolutionary temporal scales. However, planned management activities should not normally seek to replicate extreme values of the distribution if they will occur naturally.

The entire distribution of the Recommended Management Variability is important for ecosystem sustainability. Management strategies should be aimed at creating or allowing variation within the Recommended Management Variability distribution over time.

In most cases, actual data useful for defining Reference Variabilities and Recommended Management Variabilities will be limited. Consideration of the limitations of the data set, outlier points, and best professional judgement will be important in determining these parameters for the foreseeable future.

Figure 3 illustrates the steps leading to identification of desired condition. A suite of key elements and associated indicators and variabilities would be used for any analysis. The desired condition description should include quantitative values for environmental indicators.

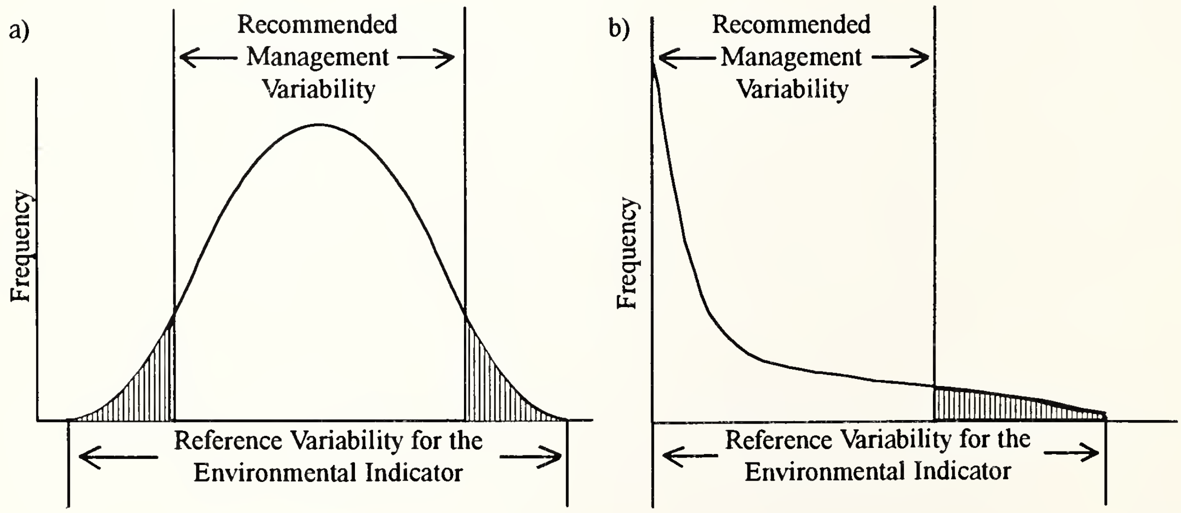

Figure 2. Examples of Reference Variability distributions. a) a bell-shaped or normal distribution, b) an inverse "J" shaped distribution.

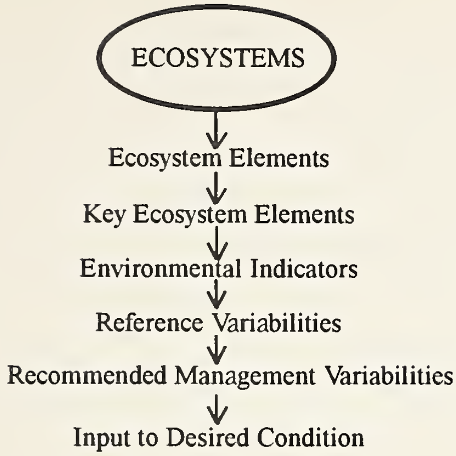

Figure 3. Generalized ecosystem analysis process. This flowchart illustrates the steps necessary to move from a broad description of an ecosystem to a more specific definition of desired condition.

What do we have?

Existing condition needs to be described in the same terms, using the same environmental indicators, as used to describe the desired condition. Existing resource condition surveys (e.g., Ecological Unit Inventories) and social sensitivity analyses can be used to define existing condition. Such surveys and analyses should be designed to provide the necessary information at the scale and resolution needed. Data should be collected under consistent standards so that corporate databases can be formed and shared across administrative, jurisdictional, and multiple ownership boundaries.

How do we move conditions from what we have to what we want?

The Conceptual Framework outlines an analysis process for comparing existing condition with desired condition, identifying management opportunities, and developing a sequence of projects to move the landscape toward desired condition (this analysis process is guided by the National Forest Management Act). This schedule of projects, expected results, and monitoring points is documented in a *Landscape Management Implementation Schedule*. As scheduled projects approach the time for implementation, specific prescriptions and required National Environmental Policy Act analysis, documentation, and decisions will be completed.

As we begin ecosystem management, we clearly recognize that we do not have perfect scientific information and know-how. We never will. We do however, recognize the need to "move forward with doubt" utilizing our best stewardship skills and an adaptive management approach. Incomplete information may challenge our scientific credibility. However, adaptive management is a credible scientific approach where information is lacking. We use our best stewardship skills in planning actions, projecting expected outcomes, and implementing according to plans. We then monitor results to verify or bring about adjustments to our plans and projections, cycling through the process time and again as we learn and improve our understanding and management through time (Figure 4).

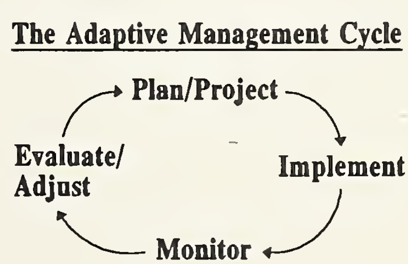

Figure 4. The Adaptive Management Cycle.

Chapter 1
Introduction

Table of Contents

Chapter 1
Introduction

What you can do, or dream you can, begin it.
Boldness has genius, power and magic in it.
Begin it now.

Goethe

Setting the Stage

Ecosystem management is the central theme for the future of the Forest Service. In June of 1992, the Chief, directing that ecosystem management be implemented, defined it as *The skillful, integrated use of ecological knowledge at various scales to produce desired resource values, products, services, and conditions in ways that also sustain the diversity and productivity of ecosystems.* His direction letter provides these additional insights about the intent of the new policy:

> **The challenge of ecosystem management is to sustain systems that are diverse, productive, resilient to short-term stress, and able to respond to long-term change....We manage the forests for specific purposes such as producing, restoring, or sustaining certain ecological conditions; for desired resource uses and products; for vital environmentalservices; and for aesthetic, cultural, or spiritual values.**

In September of 1992, the Pacific Southwest Region (Region 5) completed a strategy for accomplishing ecosystem management. It conformed to management philosophies, developed at the National level, identifying these four objectives for ecosystem management:

- take care of the land,
- address the needs of people,
- use resources wisely, and
- strive for balance.

In October 1994, the Chief issued *A Course to the Future for the Forest Service* — it described four steps which clearly articulate the agency's values and perspective on ecosystem management.

Mission - The "Mission, Vision, and Guiding Principles" of the Forest Service provides the framework for our work, and the mission "Caring for the land and serving people" embodies its spirit.

Ethics - Our land ethic is to promote the sustainability of ecosystems by ensuring their health, diversity, and productivity. Our service ethic is to tell the truth, obey the law, work collaboratively, and use appropriate scientific information in caring for the land and serving people.

Strategic Course - The course focuses on enhanced protection of ecosystems, restoration of deteriorated ecosystems, provision of multiple benefits for people within the capabilities of ecosystems, and organizational effectiveness.

Outcomes - The three primary outcomes of Forest Service actions will be healthy ecosystems, vital communities and an effective multidisciplinary, multicultural organization.

The Chief's *Course to the Future* emphasizes the continued commitment to land and service, and highlights their complimentarity and interdependence. People influence every acre of the earth's surface through their dependence on natural and cultural resources for survival and quality of life. These needs will expand with population growth, and this will be especially true in California, historically one of the fastest growing states. Land management in Region 5 must be conducted with the awareness that all ecosystems have limited capabilities, and their limits are largely ill defined. All those concerned with the management of wildlands must be mindful that science, in the Chief's words, "...can describe options for addressing management problems and provide assessments of their consequences. But science simply will not and can not give society 'the answer'. Science is only a tool — in the end, all managerial decisions are moral, not technical."

Ecosystem management is precipitating a change in the way land management agencies approach decisions. Meeting ecosystem management objectives means gaining an understanding of basic ecosystem processes and functions before deciding what management is appropriate. Management issues may influence where we conduct ecosystem analyses. But the analysis must not be constrained in its scope by issues that, in the long run, may be transient. Ecosystem analyses should address the full range of factors that affect the capability of the ecosystems to fulfill long-term resource objectives.

Ecosystem management will affect not only the information on which we base decisions, but will change how we make them. Partnerships and collaborative management are essential for arriving at realistic solutions for sustaining the diversity and integrity of ecosystems. Collaborative decision building with the public, between agencies, and with Indian tribal governments and communities is critical for successful balancing of cultural/social values and needs with ecosystem capabilities. Collaborative decision building differs from past public participation where public interaction was sought only at limited times during an otherwise closed process. Collaborative decision building strives to achieve openness in the decision making process through:

- working with people throughout the process so there are common expectations of what is to be decided,

- forming partnerships to achieve mutually beneficial goals, and

- giving all partners an opportunity to be heard and participate.

Ultimately the results must be scientifically credible, legally defensible, and socially acceptable.

The Conceptual Framework

The Conceptual Framework for Sustaining Ecosystems in Region 5 (hereafter referred to as the "Conceptual Framework") is a step in the Region's on-going effort to define ecosystem management and build a foundation for accomplishing the goals described in the Region's ecosystem management strategy and strategic issue. This is version 1.0 of the Conceptual Framework, with the expectation that refinement and elaboration will occur over time, and that further developments will be incorporated into future versions of this and future documents.

The objective of ecosystem management is to *sustain* ecosystems. The Conceptual Framework defines sustainability in terms of conserving *biological and cultural/social diversity*. Conservation of diversity lowers the risk of creating conditions that threaten sustainability. The Conceptual Framework outlines a rationale and process for sustaining ecosystems through the implementation of our Land and Resource Management Plans. It is the basis for more informed decisions regarding the myriad of

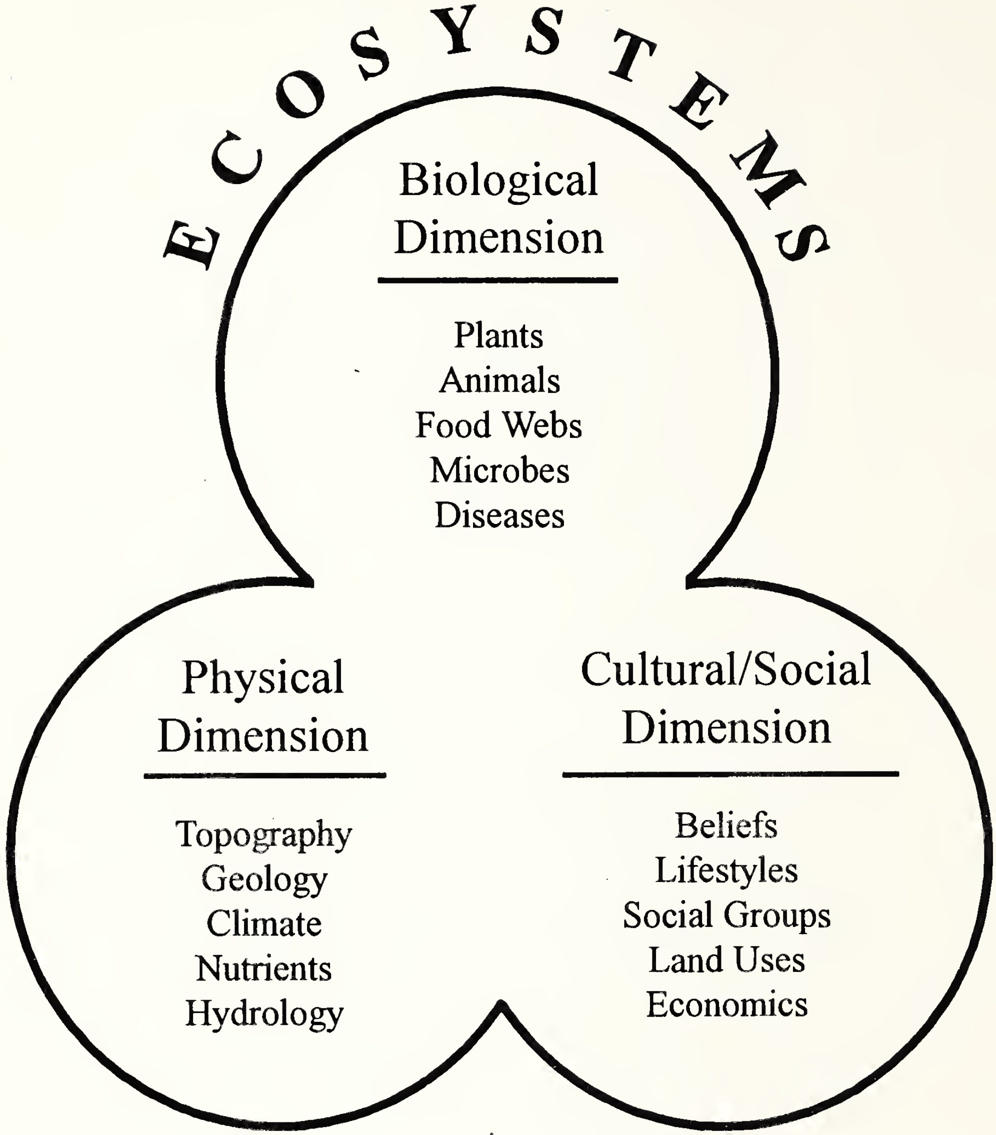

Figure 1-1. The three dimensions of ecosystems and examples of their elements.

cultural and social values attached to the ecosystems we are intrusted to manage.

The Conceptual Framework integrates the *physical, biological, an cultural/social dimensions* of ecosystems. The schematic in Figure 1-1 displays these three primary dimensions. Each dimension is shown with a few examples of mutually interacting elements.

The Conceptual Framework applies to all areas of work within Region 5. It applies to the management of Forest Service lands, to our interactions and collaborative efforts with other agencies and Tribal governments, and to our land management assistance and educational programs.

Content Overview

The Conceptual Framework addresses three major areas: scientific concepts and principles of ecosystem management (Chapter 2); the analysis and planning process (Chapter 3); and some methods and considerations for implementation (Chapter 4).

Chapter 2 establishes scientific principles, concepts, and assumptions that form the foundation of the Conceptual Framework. Parallels between biophysical principles and cultural/social concepts are established.

Chapter 3 applies these principles to the task of describing and analyzing ecosystems and using the results in planning. It shows how the objectives of ecosystem management can best be incorporated into the current planning process. This chapter explains the basis of desired conditions, how projects are generated, and how decisions are made under ecosystem management.

Chapter 4 provides an introduction to data sources, analysis techniques, and sampling considerations. The intent is to view the breadth of the analysis process and highlight a few important considerations. Many insights, problems, and innovations will arise from the implementation of the Conceptual Framework that cannot be elaborated on here, or even anticipated. Chapter 4 is a "frontier" where the Conceptual Framework leaves off and implementation begins.

Appendix A defines Key Ecosystem Elements and associated Environmental Indicators within Region 5. Elements of each ecosystem dimension and their roles at various spatial and temporal scales are identified. Elements are described for each of four hierarchical schemes based on terrestrial, hydrologic, atmospheric, and cultural/social aspects of the ecosystem.

Appendix B is an example illustrating the application of the concepts, tools, and techniques presented in the Conceptual Framework to a specific situation. Key Ecosystem Elements and Environmental Indicators are chosen, and Reference Variability and Recommended Management Variability are derived for some of the chosen indicators.

Management Content

Many efforts undertaken within Region 5 contribute to implementing ecosystem management. Some of the region-wide efforts include (but are not limited to) the Ecosystem Health and Sustainable Productivity Strategic Issue, EcoMap, Ecological Classification, Watershed Analysis, and the California Spotted Owl Environmental Impact Statement.

These five contemporary efforts incorporate one or more components of the Conceptual Framework, and they are described below.

The Ecosystem Health and Sustainable Productivity Strategic Issue identifies three goals: manage renewable resources using a landscape approach; improve current levels of ecological knowledge and understanding; and move toward a flexible and responsive organization focused on collaborative

decision making. These are the Region's priorities for ecosystem management.

The Region 5 EcoMap group is charged with identifying resource information needs, integrating inventory data bases, facilitating the development of spatial data, and identifying monitoring needs in regard to ecosystem management.

The Ecological Classification Program characterizes potential natural vegetation within the Region, which in turn reflects the ecological capabilities and limitations of sites.

Watershed Analysis is an analysis conducted in response to the *Record of Decision for Amendments to Forest Service and Bureau of Land Management planning documents within the range of the Northern Spotted Owl* (hereafter referred to as the President's Forest Plan). Watershed Analysis considers biological, physical, and cultural/social dimensions of ecosystems in describing the status of a watershed. The analysis is confined to one scale and focuses on specific issues of management concern within the analysis area.

The California Spotted Owl Environmental Impact Statement is intended to provide direction for an ecosystem approach to maintain viable populations of the California Spotted Owl. The resulting direction is intended to provide for the spotted owl, contribute to the viability of other widely distributed plant, wildlife, and fish species, contribute to the economic and social well being of local communities, and provide for sustainable levels of renewable natural resources.

The management efforts cited above are only some of the actions taken by the Region in the recent past to move toward ecosystem management. They vary in their approaches and scope. The Conceptual Framework is intended to provide a consistent and defensible scientific basis for all future analysis, planning, and management.

Summary

The Conceptual Framework is Region 5's contribution to clarifying science and perceptions about ecosystems. It is intended to facilitate clarification and help land management agencies, Indian tribes, and members of the public within California come to a common understanding of how we can sustain ecosystems. This consideration — common to all parties — implies that Forest Service analyses will consider ecosystem interactions that may extend beyond national forest boundaries.

We will implement Forest Service cooperative programs encouraging an ecosystem approach on other lands. In partnership with the State Forester and others, we will assist urban and rural communities to maintain, restore, and enhance the quality of ecosystems.

It is not a simple task to balance ecosystem concerns and interests in resource management. Our understanding of ecosystems is far from complete; we will often be working with partial information and will use professional expertise to develop estimates of sustainability. Conserving ecosystems requires evaluating benefits and risks, then acting on the best available information. As research and monitoring reveal new information, benefits and risks will be reevaluated, adjusted, and plans shaped to new realities.

This document simply provides a framework for ecosystem management. Through implementation, much additional detail will be added, fine points worked out, and thinking refined. Ecosystem management differs from our past resource management in the way we intend to conserve biological and cultural/social diversity. We emphasize outcomes—the condition of the land and community—whereas in the past the emphasis has been on outputs. The Conceptual Framework is a foundation for integration of ecosystem principles and an improved understanding of ecosystems in our management.

Chapter 2
Ecosystem Principles and Concepts

Table of Contents

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Ecosystem Principles and Concepts

A problem well stated is a problem half solved.

Kettering

This chapter introduces fundamental scientific principles and concepts that underlie an ecological approach to management of ecosystems. To work well together, the Forest Service, other agencies, universities, and the public at large need a common understanding of how ecosystems can be defined and how they function. This chapter also presents conceptual approaches to ecosystem management and develops a method for maintaining diversity and sustainability of ecosystems.

Principles and concepts from both biophysical and cultural ecological theory are presented. Many terms are similar in meaning, though they may differ in application. Where new analogies are drawn, they are specifically mentioned.

Review of Ecological Theory

Ecological theory and its application are human constructs designed to simplify and organize overwhelmingly complex systems. Defining ecosystems, describing them at various scales, and using general rules regarding their function and development help us to formulate rational management schemes. However, simplification can have drawbacks. For example, segmenting a continuum into discrete intervals or focusing on structure without recognition of underlying processes may lead to inappropriate management decisions. Thus, the implications of using these principles and concepts must be kept in mind as they are employed.

To organize our description and management, we can view ecosystems as the interconnected physical, biological, and cultural/social dimensions of the environment. Physical elements provide the basis for biotic and cultural communities. Biological elements utilize and transform physical elements and lay the foundations for cultural/social communities. In turn, biophysical elements are utilized and transformed to support cultural/social elements. Figure 1-1 gives some examples of elements within each dimension.

Humans dominate many ecosystems. Through the widespread distribution and adaptive advantage of culture, people can significantly alter the physical and biological dimensions of ecosystems (Fagan 1975:54; Bennett 1976:3; Goudie 1982:2-9,23). The intensity and scale of these cultural adaptations can vary widely—from digging a well to developing the California aqueduct system, or from pruning a patch of native redbud shrubs to introducing genetically altered crops throughout the Central Valley.

The field of cultural ecology specifically studies human adaptations to the environment. Early work focused on the interrelationships among technological, economic, and environmental variables. Later work expanded analyses to consider virtually all elements of cultural systems, and their interrelationships with the biophysical environment (Steward 1938, 1955; Rappaport 1967; Harris 1968).

Ecosystems: Components, Structures, Processes, and Functions

Definitions for the term *ecosystem* arise from both biology and cultural ecology. Consistently, they refer to a system formed by the interaction of a group of organisms — including people — and their environment. Thus, an ecosystem may be described within a rotting log, for the entire planet, or any level in between (Noss and Harris 1986).

Ecosystems have three fundamental types of *elements*: *Components* are the kinds and numbers of organisms and physical attributes that make up the ecosystem — the "pieces". *Structures* are the spatial distribution or pattern of these "pieces". *Processes* refer to the flow or cycling of energy, materials, and nutrients through space and time. Components, structures, and processes all interact and influence one another. Table 2-1 depicts examples from each of the three ecosystem dimensions.

Components, structures, and processes have various functions within ecosystems. *Functions* are the operational roles of elements within ecosystems. Functions can change over time and space and may differ considerably within and among ecosystems. For example, coarse woody debris in a fluvial ecosystem functions to produce structural variation in channel morphology and contributes to aquatic habitat diversity and complexity. It is also an important nutrient source for the aquatic system.

Scales and Gradients

We use multiple *scales* to describe and manage ecosystems. Within this organizational framework (devised by humans to meet human needs for analysis and understanding) the analysis scale selected and the boundaries used depend upon the problem or question being addressed. Spatial scales range from regions of microbial activity up to human activity on the entire planet.

The earth can be stratified into progressively smaller areas of increasingly uniform *ecological potentials.* Ecosystems are thus conceptualized as occurring in nested geographic arrangements—ecosystems within ecosystems. This offers a convenient way for organizing patterns that are generated by ecosystem processes at several scales. Heterogeneity at one scale may be organized into predictable patterns at higher scales. Repetitive patterns that are hidden, but which contribute to a larger pattern or structure, can be examined within and among the larger landscape scales. In analysis, scales that are both larger and smaller than the primary scale of analysis should be considered to reveal effects that may not otherwise be apparent.

Table 2-1. Examples of components, structures, and processes among the three ecosystem dimensions.

Dimension	Elements		
	Components	Structures	Processes
Physical	Water	Stream/Lake	Discharge
Biological	Plant	Vegetation mosaic	Photosynthesis
Cultural/Social	Road	Transportation system	Flow of goods

model of cultural refugia. In times of environmental stress, cultures coalesce in environmental oases, share and mix traits, and then disperse with new clusters of traits when climate improves. Berry's model of rapid, punctuated change is contrasted against that of gradual evolution traditionally used to account for chronological change.

Adaptation

The process of *adaptation* exists within both the biological and cultural/social dimensions, but it operates differently in each. In the biological dimension, species adapt to conditions over evolutionary time scales through genetic drift, mutation, and natural selection (evolution or evolutionary adaptation). Significant change typically requires hundreds of generations, and the potential for change (i.e., evolutionary plasticity) is ultimately dependent upon the genetic diversity of the species. Over shorter time frames, species can change their behavior in response to environmental changes (ecological adaptation).

Humans exhibit genetic, physiological, and behavioral adaptations; however, the diversity of human behavioral adaptations made possible by culture provides plasticity for the human species within the ecosystem (Rappaport 1967:241; Moran 1979:5-9; Rappaport 1990:55). Cultural adaptation allows people to rapidly adjust, accommodate, or conform to changes within their environment.

Human behavioral adaptations can be technological (clothing, shelter, tools, etc.); organizational (social status and roles; e.g., kinship and politics); and ideological (values, traditions, beliefs, philosophies) (Hardesty 1977:24). Culture provides awareness or recognition of environmental problems and the basic solutions to them and improves the effectiveness of the solutions (Hardesty 1977:24). The greatest values of these cultural adaptations are that they may be used in a variety of changing circumstances and altered at will (Stini 1975:11).

Disturbance

Ecosystems are constantly changing. They may change through succession, as described previously, or be altered by disturbance. Events which are described as *disturbances* are agents for significant change in ecosystem components, structures, or processes. What constitutes "significant" change is ill-defined, but generally the overall function of the ecosystem would be conspicuously different. Some disturbances are of biophysical genesis, while others are cultural. Some occur regularly and are relatively predictable, whereas others appear to be random in nature.

Many ecosystems have evolved with, and depend on, disturbances (Vogl 1980; White and Pickett 1985). Disturbances are typically described by type (fire, drought, flood, etc.) and may be further characterized by distribution, frequency, return interval, rotation period, predictability, area or size, magnitude, intensity, and severity. Disturbances can influence diversity and ecosystem stability by altering heterogeneity of ecosystem elements across landscapes over time.

Neither the mechanisms of disturbance nor the interactions between disturbance agents are fully understood. Disturbances play a role in ecosystem functioning. Some occur regularly through time, and species within the ecosystem have adapted to their effects. Other disturbances are unique or rare to the system and, without the opportunity for adaptation, may lead to inherent and irreversible change.

Depending on their magnitudes and scales of relevance, typical events that may disturb California ecosystems include the following: fire, insects and disease, windthrow and storm damage, floods, soil erosion, introduction of exotics, mining, timber management, livestock grazing, water control, air pollution, new technologies, wars, and epidemics.

Stability and Resilience

Disturbance and the concepts of ecosystem stability and resilience are closely related. *Stability* may be viewed as the degree to which an ecosystem's long-standing composition and structure can be subjected to agents of perturbation and still maintain characteristic components, structures, and processes. Stable systems can absorb some degree of disturbance while resisting fundamental change. During the first half of this century, ecologists hypothesized that successional development led to increasingly stable states. Recent studies have shown that this is not always a reliable assumption.

When disturbance significantly changes conditions, the ability of the system to recover its predisturbed state is its *resilience*. Ecosystems subject to frequent disturbances typically contain a greater representation of species adapted to disturbance that will aid in the system's recovery.

Stability and resilience depend upon numerous factors operating at various levels of ecosystem organization. A system disturbed beyond its limits of stability (resistance to change) and resilience (potential to recover to a similar predisturbance state) will be forced into different components, structure, or processes. The system will become fundamentally different and may not return to predisturbance conditions for a long time, if ever.

In the typical disturbance-dependent ecosystems of California, more diverse systems may tend to be both more stable and more resilient than less diverse systems. Greater biological diversity increases the likelihood that an ecosystem will contain both elements that are resistant to change as well as elements that can recover rapidly.

In cultural ecology, stability is usually addressed in terms of carrying capacity. Carrying capacity is the ability of the ecosystem to contain, absorb, receive, or hold elements without major systemic change. Industrialized societies adapt so rapidly and at such a large scale, that they can temporarily exceed carrying capacity, and may find the need to self-regulate their activities, for example, by reducing fuel consumption, limiting reproduction, or by emphasizing traditional cultural practices (Wolanski 1989).

So long as carrying capacity is not exceeded in the long term, cultural/social systems tend to be more stable where they are more diverse, as diversity provides opportunities for adaptation. As examples, the eastern California community of Bodie became a ghost town when mining of its single resource proved to be economically unfeasible. On the other hand, the northwest California coastal community around Eureka has weathered the decline in the timber industry by maintaining more diversity — a university, fishing, tourism, and a prison.

Landscape Patterns

Disturbance and succession produce a continuously changing *landscape pattern* of patches or mosaics. At some scale, a dynamic equilibrium may exist across a landscape despite the fact that the patches are constantly changing with time. In a sustainable landscape, creation of new patches is balanced by the maturation of older ones. As such, the basic notion of a stable ecosystem could prevail if examined at a larger spatial/temporal scale. Areas where landscape-scale disturbances are typical cannot be expected to exhibit such an equilibrium. A single disturbance event could affect a relatively large portion of that landscape, significantly altering the distribution of developmental stages, both spatially and temporally.

In cultural ecology, settlement pattern analysis at the community/landscape or subregional scales provides the broad scale appropriate to understanding ecosystems (Fagan 1975:56, 342-356; Hardesty 1977:11-12, 248; Jochim 1990:80-81). For example, the historic subsistence cycle of hunters and gatherers shows a stable pattern at large scales, where food is obtained seasonally throughout a drainage or subregion as the resources become available. At any single location, the overall use pattern would not be observable and might appear erratic.

Ecosystem Stress, Ecosystem Health, and Thresholds

Three terms are commonly used in discussions of ecosystems: *stress, health, and thresholds.* Stress has been viewed as a condition where disturbance has pushed an ecosystem beyond its ability to resist or recover. However, ecosystem stress and its converse, ecosystem health, are value-laden terms that have not been specifically and consistently defined. Therefore, we choose not to use them in our approach to ecosystem management.

Also, there are theoretical thresholds of change or disturbance, which if surpassed, will result in fundamentally different ecosystems. While being able to specify these thresholds would be of tremendous use, there are presently few predictive approaches to determine them. In general, thresholds are only recognized once they are exceeded. Given the lack of information on thresholds, we choose not to use this term in our approach. Rather, we identify recommended ranges or distributions of elements that we are relatively sure lie within such thresholds.

Diversity

Diversity is an important concept for all three dimensions of ecosystems: physical, biological, and cultural/social. In discussions of diversity one cannot separate the physical dimension from the biological dimension; changes in physical diversity are reflected directly in biological diversity. Diversity in biophysical systems tends to also be reflected as diversity in cultural systems and there are clear links between the two (Hardesty 1980). As an example, consider the great diversity of both California's habitats and cultures. What follows is a parallel discussion of biodiversity and cultural diversity, and reasons and methods for conservation.

Biodiversity

The diversity of living organisms, or *biodiversity*, is an important characteristic of ecosystems across all scales. Retention of the functional roles that species fill within naturally evolved systems, as well as the genetic resource that they contribute, is an increasing focus of conservation. Initial efforts focused on conserving a relatively small number of species. Recently the emphasis has shifted to the need for conserving all species.

Definitions of biodiversity have evolved to include the variety of organisms, their interconnections, and their associated ecological processes. Conservation of biodiversity is important at the genetic, species, and ecosystem levels of organization. Thus, strategies should strive to conserve the full array of diversity and processes within and among species and ecosystems.

Reasons for Conserving Biodiversity

Reasons for conserving biodiversity are varied and broad in scope. Fundamental reasons include maintaining the viability of species and the stability and resilience of ecosystems. Although species extinction is a natural process, the worldwide rate of loss has accelerated dramatically in recent times. The cumulative loss of species and associated ecological function could change critical large scale functions of the world ecosystem.

Ultimately, all things that people believe and do occur within a cultural/social context; thus, the success of conservation efforts is dependent on attitudes, beliefs, values, lifestyles, lifeways, and current and potential uses of various ecosystem components. These cultural/social values are reflected in a number of laws, regulations, and governmental programs aimed at maintaining and enhancing diversity. Examples include National and State parks, forests, and wildlife reserves, the Endangered Species Act, National Environmental Policy Act, National Forest Management Act, the

Clean Air Act, Clean Water Act, etc. The National Forest Management Act and Endangered Species Act provide primary direction to the National Forests for conservation of biodiversity. They recognize that public lands can play an important role in conservation of biodiversity for the nation.

Cultural Diversity

Culturally diverse systems are characterized by a multiplicity of customs, lifestyles, social organizations, and economies. Diversity is reflected in the structure of the society, population, economy, etc., at the community/landscape, subregional, and regional scales. Cultures with diverse components, structures, processes, and functions generally adapt readily to change, cultural or biophysical. If carrying capacities are not exceeded, diverse human systems tend to have greater stability than those with less diversity. At broad scales, human societies are generally more diverse, and as a result tend to be more stable (Moran 1979:103; Wolanski 1989; Zarnowitz 1990).

Diverse metropolitan areas easily adapt to changes in population or subsistence; however, they may exceed carrying capacities. Nevertheless, population loss (or gain) in large urban areas is virtually undetectable, whereas population changes in small or rural communities can significantly affect values, services, and other cultural elements at the community level.

Individual communities support fewer functions and therefore have fewer opportunities to adapt to change. Specialized communities may need to rely on diversity found at a broader scale.

Only the most diverse social and economic systems can support highly specialized human activities and endeavors (Isard 1960, 1975). Specialized health care, premier educational and research institutions, complex financial and legal services, and the complex infrastructure needed to support international trade and services can generally be supported only by metropolitan centers.

Today many local, traditional cultures are confronting social, technological, and economic changes that drive them to acquire or borrow a variety of cultural innovations. Examples can be easily cited. Because of reduced timber production wrought by various endangered species considerations, some timber-dependent communities are turning to tourism and recreation to improve and diversify their local economies. Other towns have deliberately chosen to maintain their historic characters for the charm, tourism and recreation, or community and ethnic identity values they engender.

Reasons for Conserving Cultural Diversity

Diversity is important for the cultural as well as the biophysical dimension. Changes and disturbances are more easily adapted to in diverse systems. Diverse systems are characteristically stable (Moran 1979:103). In the opinion of some ecologists, diversity is essential to cultural survival; monocultures are doomed to extinction (Wolanski 1989:412-413, 426-427).

Society places a value on maintaining diversity because our society is, in itself, a composite of so many cultures, and because cultural diversity adds to the human life experience — in addition to enhancing stability. Programs to maintain folk cultures and folk art, the popularity of ethnic foods and music, laws to ensure equal representation and prevent discrimination all emphasize the values of cultural diversity.

These societal values have been reflected in a number of laws, regulations, and governmental programs aimed at maintaining and enhancing diversity. Examples that emphasize cultural diversity include: the American Indian Religious Freedom Act, the National Historic Preservation Act, the Civil Rights Act, the National Endowment for the Humanities, public and private education programs, historic parks and monuments, culturally oriented museums and relatively open immigration policies. Examples that emphasize economic diversity

include a host of programs aimed at small business development, rural economic diversification, urban redevelopment, overall economic development and stability, tariffs and subsidies.

Biodiversity Conservation Methods

Differing conceptual approaches for conserving biological diversity have been formulated that deal with two broad philosophical aspects. The first aspect has to do with the focus of management efforts: *biocentric* or *ecocentric*. Strategies that focus on providing sufficient amounts and arrangements of habitats to conserve desired individual and groups of species are called biocentric, while those that focus on providing landscape patterns that enable ecological processes to operate at several scales are termed ecocentric. The second philosophical aspect has to do with the level of refinement for the management efforts: *fine-filter* or *coarse-filter*. Strategies designed to address the needs of individual, at risk species are called fine-filter, while those that seek to retain communities of organisms are coarse-filter.

Biocentric Coarse-Filter/Fine-Filter Approaches

The traditional Forest Service approach to conserving biodiversity has been a species-focused or biocentric approach. Focus has been on Federally threatened and endangered and Forest Service sensitive species, game species, and selected species of local interest. These species are traditionally used as management indicators, and are often chosen to act as proxies for the habitat needs of many other species. The Forest Service has also employed limited community-focused biocentric conservation efforts such as establishment of Research Natural Areas.

Use of individual management indicator species as proxies for the habitat needs of other species is inconsistent with the concept that each has individual niche requirements. Today, biocentric approaches focus on combinations of coarse-filter and fine-filter methods. Large coarse-filter reserves provide protection for entire communities of organisms, while fine-filter strategies protect individual species at risk.

The basis for the biocentric coarse-filter/fine-filter strategy is a system which inventories and evaluates "elements of diversity" (e.g., species, community-types, seral stages, bird rookeries, geologic features). These "elements" are ranked by rarity and endangerment (based on frequency and extent) at both small and large scales. Specific areas or sites are further evaluated for quality, condition, viability, and defensibility of the particular element. The coarse-filter approach is used for community inventories and the fine-filter for species inventories. The system enables land managers to prioritize areas selected for either reserves or for a particular type of management depending on the elements found on the site (e.g., an endangered species, a rare community).

The threatened, endangered, and sensitive species programs at the state and Federal levels are generally regarded as appropriate fine-filter conservation efforts. This conservation approach encounters little debate regarding the need to provide attention to individual species at risk. But considerable debate about biocentric coarse-filter reserves has occurred, specifically in regard to appropriate sizes and numbers of reserves. Most agree that reserves for any target species must permit dispersal of young, a minimum number of breeding individuals, and life cycle needs. They should be of a size to offset the adverse impacts of activities along their borders. *Gap analysis* is a tool for addressing these concerns by identifying candidate reserves based on existing suitable habitat areas that are not protected by existing reserves.

The focus of the biocentric approach has changed over time from a small number of key species, to groups of related species, to entire communities of organisms. This approach has not yet been used for developing strategies for conserving the full range of biodiversity in California or elsewhere. Such an

approach would involve examining the habitat and biological needs for the full range of organisms within all the communities and ecosystems in the area of interest. Definition of species-specific gap analysis needs for all species involved within a coarse filter framework is particularly problematic. Such an endeavor would be tremendously complex, costly, and impracticable at any sort of extensive scale.

Theoretical weaknesses in the biocentric coarse-filter approach are also apparent. These include:

- Indefensible use of only one type of conservation unit (e.g., a plant community) when other patterns and/or scales may be of equal or greater importance to maintaining biodiversity;
- Ignoring potentially important interactions between communities (e.g., nutrient flows from a terrestrial community to an adjacent aquatic community);
- Assuming communities are stable, predictable entities;
- Focus on dominant community species that may not represent the needs of less abundant or conspicuous members;
- Ignoring the contemporary influence on disturbance regimes and patterns of representative communities.

Ecocentric Coarse-Filter Approach

A different approach to conserving biodiversity is an ecosystem-focused or ecocentric approach. This coarse-filter approach takes the concept of focusing on a conservation unit broader than a community and expands it further. Reserves are no longer the basic part of the conservation scheme — the entire landscape matrix assumes that role. The focus is on providing components, structures, and associated processes at each scale in a hierarchically arranged landscape that mimic those in natural ecosystems, thereby providing for the full range of biological organisms in each ecosystem. If entire ecosystems could be managed to maintain biodiversity, the need for "reserves", in the traditional sense, would be greatly reduced or eliminated since the entire managed system would provide for the needs of all species, physical elements, processes, and relationships.

The ecocentric approach is becoming an attractive alternative because it offers a conceptually sound and potentially achievable approach for addressing the full range of biological diversity. It is not necessary to have detailed information about all the organisms and processes in an ecosystem to develop a management scheme based on maintaining the integrity of the ecosystem across the landscape (Hunter 1991).

Because the components, structures, and processes in any landscape scale are dynamic in space and time, most programs that use this strategy specify that the desired condition for landscape elements lies within distributions bounded by the expected variation produced in nature. An ecocentric approach is a practicable approach to conserving biodiversity given the complexity and dynamic nature of ecosystems. Its theoretical weakness is that it may not recognize critical individual species needs if they are not among the landscape elements defined under desired condition.

An Applied Biodiversity Conservation Management Approach

Given the practicality and potential efficiency of the ecocentric coarse-filter approach, it clearly should be one facet of the Region's strategy for maintaining biological diversity. This moves management from zones and reserves to the entire landscape matrix. It coincides well with the philosophy of ecosystem management, and it is ecologically defensible when applied in a scientifically rigorous and well documented fashion. However, scientists and land managers are just beginning to understand the intricacies of ecosystem dynamics and functions.

Implementation of the ecocentric coarse-filter approach presents some risk, as does implementation of any approach, because it requires that we understand the consequences of our actions.

The more we can learn about ecosystems, the greater the likelihood that our assumptions about ecosystem response will be correct, and that we will achieve the conditions we desire. It is this learning that has led us to an ecocentric approach at this time.

Our current level of understanding compels us to also continue our use of biocentric fine-filter approaches for the following reasons:

- It is prudent and sound to use fine-filter methods and monitoring to evaluate the effectiveness of our coarse-filter approach.
- Fine-filter methods will be needed for some time to sustain species already known to be at risk, as well as species that will become or be recognized as at risk in the future.
- Some species that use National Forest lands are critically dependent on habitat conditions elsewhere in the world as well (e.g., neotropical birds), and fine-filter monitoring is necessary to continue tracking the status of such populations.

The Region's conservation strategy should continue to emphasize refinement of our biocentric fine-filter approach as a complement to the ecocentric coarse-filter approach. Species at risk may require reserves or management strategies in the short term, that coarse-filter methods will not reveal. Fine-filter strategies should enhance at-risk populations to a point in the future when coarse-filter management will provide for their continuing needs.

These approaches complement one another; indeed, neither is a defensible conservation strategy without the other. The ecocentric coarse-filter approach particularly relies upon the presence of a fine-filter approach as a safety net, because incomplete information may lead to false assumptions about ecosystems, and species or processes may suffer as a result. A well designed fine-filter approach can serve as an early warning that some aspect of the coarse-filter approach needs adjustment. To be most effective, our current fine-filter programs should be broadened to better assess species potentially at risk, not just identify those already declining. The coarse- and fine-filter approaches as proposed combine a broad application of general ecosystem relationships (encompassing all the intricacies of which we are unaware) with the specific relationships we do understand.

Cultural Diversity Conservation Methods

At Federal and State levels, governments administer cultural diversity programs that include regulation of individuals, businesses, public agencies, taxes, tariffs, subsidies, grants, and legal penalties. The U.S. Department of Agriculture has a rural economic development and diversification mission. The Forest Service administers several of these programs, using a mix of technical and financial assistance. Many of the more general acts (e.g., Civil Rights, NFMA, NEPA) have the effect of empowering local groups to define their own cultures, thus creating more diversity.

These long-standing programs, regulations, and procedures are now augmented by ecosystem management. Cultural diversity is seen as a means to sustain viable cultural/social dimensions of ecosystems, and, because this kind of diversity multiplies the complexities of the web of human/land relationships, the diversity of ecosystems as a whole. Therefore, an increased emphasis is placed on working with the public — including nontraditional users — in a collaborative fashion to identify, accommodate, and perpetuate diversity.

Another new aspect is paying closer attention to broader scales; looking beyond the site or district to landscape, land use, and settlement patterns; beyond the traditional local community perspective to broader subregional and regional perspectives. The resulting broader analysis will focus management of ecosystems to support this cultural diversity.

Cultural Open-System/ Closed-System Approaches

Broad scale analyses that incorporate culturally diverse values into decision making can be done via open or closed system approaches. These can be used to complement each other — to manage for broad scale diversity, generally through the use of an open-system approach, or to focus on specific elements in need of special consideration through the use of a closed-system approach.

Open-system approaches emphasize the interrelationships among all elements of cultural/social systems, and among all dimensions of the ecosystem. Because diversity is a key means for maintaining cultural — and ecosystem — stability, cultural elements would be broadly managed to conserve diversity. They would be managed to accommodate diverse views and values, meet diverse needs, maintain diverse cultures and their environments. In open-system approaches, settlement patterns, land use patterns, regional analyses, and other broad scale analyses often (though not solely) provide appropriate levels of resolution (Hole and Heizer 1969: 373-374; Fagan 1975:52-56; Moran 1979:9-11).

Closed-system approaches focus on a specific culture, on a specific cultural element across an array of cultures, or between an individual element or a specific culture and its environment. They treat cultures as unaffected by outside forces; as maintained internally, with few linkages to the outside world (Moran 1979:9-11). Closed-system approaches can be used to focus management on specific cultural needs or issues, or to manage diversity for specific cultural elements or segments of cultures.

Ecosystem Sustainability

Sustainability is an applied and evolving concept in land management. It has been used to address both outputs (e.g., sustained yield) and conditions (e.g., sustaining ecosystems). Goals often are described by such words as "continuous" or "in perpetuity". The Chief has asserted that ecosystem management will lead to "sustainable ecosystems", where the ecological system is the context for management rather than just its individual parts.

Evolution of the Concept

The concept of sustainability did not originate in law; rather, laws were established reflecting the ideals of society. Traditional sustainability was defined by the capability of lands managed with a particular emphasis to continually produce the emphasized commodity or amenity.

Over the years, Congress has specifically referred to an increasing array of resources. Key acts chronicle how ecosystems and our understanding of them have been legislatively addressed. This legislation reflects an evolving mandate for sustainable management of forest ecosystems.

- Organic Administration Act of 1897
- Antiquities Act of 1906
- Sustained Yield Forest Management Act of 1944
- Multiple-Use Sustained Yield Act of 1960
- Wilderness Act of 1964
- National Historic Preservation Act of 1966
- National Environmental Policy Act of 1969
- American Indian Religious Freedom Act of 1970
- Endangered Species Act of 1973
- National Forest Management Act of 1976

The New Ecosystem Management Policy and Its Implications

Under the new Forest Service Ecosystem Management policy the objective is to manage "sustainable ecosystems". They should be managed to retain their integrity — their biologically and culturally diverse components, structures, processes, and interrelated functions. The concepts of ecosystem management and ecosystem sustainability are tremendously appealing because they support ecological values without rejecting human uses.

Ecosystem management calls for sustaining ecosystems — their physical, biological, and cultural/social dimensions. This implies that the goal is possible; that we can meet the challenge socially, are committed ethically, and that we have the scientific wherewithal to measure our success. This can lead to paradoxical social challenges. How will we manage when physical, biological, and cultural/social elements cannot all be sustained?
Such questions are difficult for society to resolve, particularly at a large scale.

Stewardship ethics in support of more holistic management have developed with increased scientific awareness and evolving social perceptions. Although the ethical desire is in place, scientific wherewithal is not as complete. Scientific understanding was arguably adequate for forest management objectives which in the past focused on a sustained yield of timber.

Diversity represents the integrity of an ecological system. The more the integrity can be maintained, the lower the risk to sustainability of the ecosystem. If components, structures, or processes are irretrievably lost, the ecosystem is not sustained.
At present, suitable measurement of biological diversity as a whole is problematic: we have gained enough knowledge to begin to understand how much we do not know.

Forest management planning has typically only considered the yield of one or a relatively few products over an extended time. When we consider sustaining ecosystems, we need to project activities and effects over time frames that are as long or longer than those previously used before. Additionally, our activities and effects are spatially as well as temporally linked, and we must evaluate a potential multitude of components. Such long-term planning presupposes a great deal of predictability and environmental stability. Early theories in plant succession depended upon predictable paths leading to stable, self-perpetuating climax states. Our long-term planning, and indeed the concept of sustainability itself, are founded on similar notions of predictability and stability. More recent and reliable data on ecosystem dynamics have revealed that landscape change is more dynamic and chaotic — less predictable — than previously thought. This realization means that the task of ecosystem management is inherently more complex.

Moving Forward with Doubt

The concept of sustainability to be applied to National Forest management has been incorporated into direction despite doubts of how to achieve it, and its meaning within the dynamic systems we manage. It would be vastly reassuring to us if we had the scientific information and know-how to ensure successful management of sustainable ecosystems. In an absolute sense, it is doubtful that we ever will.

The dilemma, then, is whether to proceed with less information than we would like — or to not proceed at all. If we do not proceed, we still run the risk of dire consequences — a situation that forest management has often faced. Stewardship, utilizing available science in combination with our best professional and ethical judgment where information is missing, is required to meet this challenge. An adaptive management approach is used to incorporate scientific understanding and knowledge as it evolves.

Certain points are very important when we plan for management of dynamic systems. Although nature constantly changes, we do not have to accept all change (e.g., away from desired conditions).

Management strategies can be developed to deal with inevitable change through responsible stewardship that accounts for it, plans on it, and compensates to meet desired conditions through time.

Management Premise

How do we sustain ecosystems that are so dynamic, where change is part of their very nature? Sustainability, rooted in ideas of environmental stability and predictability, may be more of a myth than a realistic concept. However, sustainability is axiomatic to land management, and ethics demand our best stewardship to achieve it. A management premise is necessary to deal with the issue of sustainability. Foundational to this premise are three assumptions:

1) **Ecosystems adapted over extended time periods, in total, present the best chance for sustainability through the future. For biological systems, this would be systems evolved through evolutionary time.**

Systems that have evolved with changing conditions over time are assumed to represent the best medium for sustaining biodiversity; the species and functions. Social/cultural systems tend to become diversified with adaptation over time and changing conditions, thus become more stable.

2) **Our best predictions of ecosystem response to management actions and anticipated disturbance represent a reasonable basis for management planning and projections.**

Our predictive capabilities are founded on some assumed degree of stability — reliable patterns, developmental rates, and cycles — otherwise, prediction is impossible. As a basis for long-term plans and projections, relatively constant environmental conditions would be assumed — with consideration of more common disturbances such as fire, even introduced fire. In more sophisticated approaches, risk assessment may be employed to predict the likelihood of various development trajectories.

3) **Management designed to maintain or reproduce key components, structures, and processes is the most likely management approach to sustain ecosystem integrity and productivity.**

For biological systems, assumption 1 asserted that systems which evolved through evolutionary time present the best chance for sustainability. People seeking to provide for contemporary human needs cannot reproduce evolved biological systems "in total". Modern technology introduces influences which are different from the evolved system elements and disturbances.

Based on our most current understanding of ecosystems, we have begun to replicate key elements: snags and down logs in stands, structure and patterns across landscapes, and disturbance regimes such as fire. We recognize the importance of these elements to ecosystem functions, and ecosystem management is intended to maintain, as well as restore, functionality and integrity to ecosystem elements threatened by less holistic past practices. Efforts to blend management with evolved processes, through either working with processes themselves or mimicking their effects, are the beginning of management of ecosystems in the Forest Service to produce both desired products, services, and conditions as well as sustainable systems.

We must remain aware that structure is an emergent property of components and processes. Replication of structure alone will not guarantee that components, processes and their associated functions will be maintained. As we move forward with ecosystem management, we need to consider both external and internal influences and design our management practices to reproduce them. Examples might include restoring systems highly altered by past fire protection through multiple prescribed burns or mechanical treatments followed by underburning. We may replicate stream channel maintenance by using flushing flows below dams.

Ecosystem management within the premise will maintain ecosystem richness, distribution, and connectivity across landscapes at various scales. We expect to learn as we go. Our management over time can be viewed as a large and fairly loosely controlled set of experimental manipulations. By comparing present responses and conditions to historical data, we can identify ecological mechanisms and processes. Once we have defined what processes are operating, we can prescribe management practices to produce the conditions we desire.

Reference Variability

In applying the management premise, we will maintain Key Ecosystem Elements (components, structures, and processes) to produce sustainable ecosystems. This is done by managing Environmental Indicators within *Reference Variabilities.* Environmental Indicators are measures of Key Elements that reflect ecosystem function and integrity. Reference Variability has been referred to elsewhere as "natural range of variability" or "range of historic variability". It is the distribution of the data values for an Environmental Indicator over a selected period of time (for biological Indicators, an evolutionary time period). Management to restore and maintain Environmental Indicators within Reference Variabilities will produce sustainable conditions.

Reference Variability Concept

Under the Reference Variability management philosophy, conservation of diversity depends upon managing Key Ecosystem Elements within the bounds of variation that have occurred over extended time periods. This coarse-filter/open-system approach assumes that over time, such management will sustain the ecosystem as a whole. If Environmental Indicators are within Reference Variability, then the system is judged as sustainable.

The fine-filter component of the approach identifies additional, species-focused Elements of concern for analysis and accommodation. This strategy implies that managers can prescribe treatments with predictable effects aimed at producing conditions within Reference Variabilities over extended periods of time. The stochastic and complex nature of systems will challenge our ability to do this, particularly at smaller scales. However, managing for conditions similar to those that have occurred in the past provides a valuable and responsible framework for sustainable ecosystem management. Use of the closed-system approach helps focus on cultural elements of particular concern.

Reference Variability analysis for biological dimensions will require identifying disturbance regimes (historical and current, internal and external), describing how they affect the Elements of interest, and estimating the distribution of values experienced by the element over an evolutionary time scale (we suggest as long a period as possible, within the last 10,000 years). For cultural/social systems, analysis will require the identification of historical changes in the magnitude, intensity and duration of Environmental Indicators. The time period used depends on the question and the Environmental Indicator, but needs to be long enough to establish trends or models.

Reference Variability values should be used as a benchmark for the sustainability of ecosystem conditions. Management practices should not produce highly disruptive effects over the landscape even though this may be within Reference Variability. A more limited distribution may present less risk and be more useful for planning purposes (see Recommended Management Variability section below).

Managing Outside Reference Variabilities

How sustainable are highly altered systems? Some systems have been altered strongly by impacts from contemporary humans, including development,

introduction of non-native species, air pollution, and alteration of natural fire regimes. Some Environmental Indicators will be outside Reference Variabilities, and overriding factors may make them unattainable or undesirable, particularly where people are an integral part of the new, highly altered system. If Environmental Indicators are not all within Reference Variabilities, it does not mean that the ecosystem is necessarily unsustainable. For example, synthetic systems, such as modern agriculture, may be sustainable — if society decides to maintain the "inputs" (such as irrigation, water, and fertilizer) from outside the system. In such cases, analysis and justification of why such systems are sustainable and desirable would be necessary.

Recommended Management Variability

A Reference Variability represents the full range of potential values for an Environmental Indicator — resulting from natural disturbances and internal changes over hundreds to thousands of years. This range would include infrequent, high-intensity events. Less abstractly, many people would call them natural disasters, such as 500-year floods, droughts, hurricanes, extreme heat and cold, large fires, or vulcanism. The role of these events in maintaining ecosystems is not well understood, though their importance is generally accepted.

The entire Reference Variability range is important to ecosystems. However, we have ample reasons for managing within a more limited range. We will be subjected to catastrophic events — despite our best efforts — no matter how we manage ecosystems. For us to replicate nature's extremes would be ecologically risky and politically problematical. It is more prudent to manage within a subset of Reference Variability ranges. This is *Recommended Management Variability.*

The intent behind determining a Reference Variability and a Recommended Management Variability for each Environmental Indicator is to define a distribution of conditions that will sustain an ecosystem. Forest Planning Standards and Guidelines can be viewed as a precursor to Recommended Management Variabilities. Water quality Best Management Practices (BMPs) seek to limit offsite erosion to normal baseline levels even though we realize that significant natural events can produce far higher erosion levels. We may also try to develop and retain diverse wildlife habitats over a landscape that may have historically evolved with less diversity.

Hierarchies

Ecosystem Hierarchies

Ecosystems are conceptualized as occurring in nested geographic arrangements called *hierarchies.* Hierarchies offer a convenient way to organize information about ecosystems so they can be compared and understood. Patterns generated by ecosystem processes may be apparent at different spatial and temporal scales (Allen and Starr 1982). A view of broader scales is particularly important in cultural/social analysis, where structures and processes can operate over large regions. Hierarchies are useful tools for observing Ecosystem Elements in their context, and for understanding interdependence and interrelationships. They provide structure for analysis of the parts and for synthesis of ecosystem data into a whole.

No one spatial hierarchy captures all dimensions of ecosystems. In essence, ecosystem processes and functions operate over varying environmental gradients such as temperature, climate and geology. For example, aquatic processes and functions operate within physiographic units called watersheds, but terrestrial ones, such as fire, frequently tend to operate over climatic and elevational gradients that result in different ecological boundaries. Analysis of many air quality issues requires use of air basins, generating another set of boundaries. While some cultural processes, such as subsistence, are closely linked to specific ecological

zones, the adaptive techniques of humans facilitate movement from one zone to another with relative ease.

To effectively analyze all relevant ecosystem processes and functions operating on such varying gradients, appropriate classification systems must be used. These differing ecological and cultural boundaries or gradients are reflected in the following four Ecosystem Hierarchies used throughout this Conceptual Framework:

- Terrestrial Ecosystem Hierarchy
- Hydrologic Ecosystem Hierarchy
- Atmospheric Ecosystem Hierarchy
- Cultural/Social Ecosystem Hierarchy

Each of these hierarchies has multiple scales. The biophysical hierarchies — land, air, water — can be characterized by location, or by land unit measures. The cultural/social dimension is only roughly similar, in that discrete spatial locations are not always applicable. Table 2-2 shows how the scales within the hierarchies are related. The biophysical hierarchies are bound by acres and square miles, while the cultural/social scales occur along a gradient from few individuals to many.

When considering ecosystems, it is generally at the landscape/watershed scale and above that sustainability can begin to be addressed.

It is important to recognize that these hierarchies represent just four ways of looking at an ecosystem. There are many important links and relationships among the Elements of these hierarchies. For example, aquatic systems are linked or integrated with surrounding terrestrial systems through runoff, sedimentation, and migration of biotic and chemical elements (USDA 1993); spatially, the corresponding subwatersheds and watersheds may fit within a given terrestrial landscape or they may overlap onto adjacent units.

Interrelationships between terrestrial, aquatic, and atmospheric systems are exemplified by carbon, nitrogen, and sulfur cycles. People interact with and influence all of the biophysical hierarchies; they manipulate flora and fauna in the terrestrial system, impound and transfer water among watersheds

Table 2-2. Scale comparison among hierarchies. This table illustrates the correlation among the individual scales within each hierarchy. Although the cultural/social dimension does not always conform to land unit measures, the designated levels roughly relate to those within the biophysical hierarchies.

Scale[1]	Terrestrial	Hydrologic	Atmospheric	Scale	Cultural/Social
up to 100s of acres	Land Unit	Site		Smallest Scale	Individual/ Social Group
100s - 1000s acres	Landscape	Subwatershed/ Watershed	Watershed		Community/ Landscape
10s - 1000s square miles	Subregion	River Basin	River Basin		Subregion
> 10,000 square miles	Ecoregion	Ichthyological Province	Air Basin	Largest Scale	Region

[1] From USDA. 1993. National hierarchial framework of ecological units. USDA Forest Service, Washington D.C.

within the aquatic system, and change the mix of gases within the atmospheric system. These ecosystem hierarchies are to be used in conjunction with one another so that pertinent information may be extracted from each hierarchy as it applies to a given analysis area.

Descriptions of Hierarchies

Terrestrial Ecosystem Hierarchy

The Terrestrial Ecosystem Hierarchy has four levels:

- Land Unit
- Landscape
- Subregion
- Ecoregion

Over the years several classification schemes have been developed to describe terrestrial ecosystems of California. In November of 1993 the Forest Service was directed to begin using the National Hierarchy of Ecological Units in planning, research, and cooperative efforts. This document will address and use this system, referring to it as the Terrestrial Hierarchy (Figure 2-2).

The Terrestrial Hierarchy uses climatic regimes as the dominant criteria for classification at larger scales (Table 2-3). Geomorphic processes, soils, and potential natural vegetation communities assume equal or greater importance than does climate at smaller scales. At each scale abiotic and biotic components are integrated for delineation of geographical areas with similar ecological potential.

The Terrestrial Hierarchy describes ecosystem potentials by mapping out relatively stable ecosystem components called *ecological units*. Ecological maps delineate physical and biological systems using elements that are relatively stable at a given scale. They use features that exert primary control on ecosystem processes and patterns in their construction. Ecological units at Terrestrial Hierarchy scales are shown in Figure 2-2.

Ecological units provide basic information for natural resource planning and management. They may be used to:

- delineate ecosystems
- conduct environmental analyses
- assess resources
- establish desired conditions
- manage and monitor natural resources.

Ecological Unit Inventories are used with other inventories at the appropriate scale to describe ecosystems. They are basic to accomplishing ecosystem management.

When considering elements and functions affected by hydrologic processes, analyses are based on an aquatic or hydrologic classification scheme. Hydrologic-based analysis units have boundaries that are easily identified along river basins and watersheds. The aquatic biota assemblages and large scale aquatic ecological boundaries in California can be grouped in the ichthyological provinces (Moyle 1976). In most cases watershed divides can be readily located on the ground and on topographic maps. A map of ichthyological province boundaries (one scale in the Hydrologic Ecosystem Hierarchy) is provided (Figure 2-4). Ichthyological provinces are used as the basis for detailed descriptions of aquatic ecosystems. The Hydrologic Ecosystem Hierarchy presented here nests within and complements the recently developed National Hierarchy of Ecological Units.

The five hydrologic scales delineated above can be used to inventory and assemble data for analysis and management. Project planning at the site level may need to draw upon information at the next larger scale — the watershed or subwatershed. For projects and analyses related to aquatic vertebrate species viability the appropriate aquatic scale of analysis will often be the ichthyological province.

Atmospheric Ecosystem Hierarchy

The Atmospheric Ecosystem Hierarchy includes a single layer of air basins. California is divided by

Fig 2-2. Terrestrial ecological unit boundaries for some scales of the Terrestrial Hierarchy. Boundaries come from the National Hierarchy of Ecological Units (USDA 1993).

Although some interactions among plants, animals, and people occur across boundaries of ecological units this does not negate their utility. Ecological units can be aggregated or divided as needed to focus on relevant issues and concerns (USDA 1993). Exact boundaries for each level developed in map format may not fit every analysis. An example of terrestrial boundaries is shown in Figure 2-3, which shows floristic units for the State. Developing boundaries for analysis, however, will not change the boundaries of ecological units.

In some cases, an ecological unit may *be* the analysis area. In other cases, watersheds, existing conditions, management emphasis, proximity to special features (e.g., research natural areas, wilderness, or urban areas) may define an analysis area.

Hydrologic Ecosystem Hierarchy

The Hydrologic Ecosystem Hierarchy has five levels:

- Site
- Subwatershed
- Watershed
- River basin
- Icthyological province

Table 2-3. National hierarchy of ecological units.[1] This table summarizes the ecological units, purposes, and area for each of the four planning and analysis scales.

Planning and analysis scale	Ecological Units	Purpose, Objectives and General Use	General Size Range
Land Unit Land Type Phase	Land Type	Project and management area planning and analysis.	Up to 100s of acres
Landscape	Land Type Association	Forest or area-wide planning and watershed analysis.	1,000s to 100s of acres
Sub-Ecoregion	Section Subsection	Strategic, multi-forest, statewide, and multi-agency analysis and assessment.	1,000s to 10s of square miles
Ecoregion			
Global	Domain	Broad applicability for modeling and sampling.	1,000,000s to 10,000s of square miles
Continental	Division	Strategic for planning and assessment.	
Regional	Province	International planning.	

[1] Source: USDA. 1993. National hierarchical framework of ecological units. USDA Forest Service, Washington D.C.

Figure 2-3. Floristic Provinces and Regions of California from Hickman (1993). Boundaries based on botanical distributions.

mountain ranges into discrete air basins. The air basins are the fundamental large scale unit in the atmospheric hierarchy, while river basins and watersheds are recommended for analysis at smaller scales (as reflected in Table 2-2). A map of air basin boundaries (one scale in the Atmospheric Hierarchy) is provided (Figure 2-5) as an example.

The basins differ in air quality, with variation in local weather patterns, climate, and emissions. A number of terrestrial and aquatic indicators of air pollution have been identified (Peterson et al. 1992). These include plant species, aquatic organisms, lichens and other receptors with known sensitivity. Both the Terrestrial and Hydrologic Ecosystem Hierarchies can be used to evaluate effects of air components on sensitive receptors. Questions concerning impacts of atmosphere on terrestrial plants are best asked using the Terrestrial Hierarchy, while questions about aquatic sensitivity are best considered using the Terrestrial Hierarchy and overlaying the Hydrologic Hierarchy. Neither the Terrestrial nor the Hydrologic Ecosystem Hierarchies are adequate to monitor discrete levels of criteria pollutants and other atmospheric components.

Cultural/Social Ecosystem Hierarchy

The Cultural/Social Ecosystem Hierarchy has four levels:

- Individual/small group - individuals, nuclear families, small groups,
- Community - urban, suburban, and rural communities and towns and landscapes, larger groups, i.e., traditional cultural groups, and commercial groups,
- Subregional unit - city and town complexes, county, larger rural or surrounding landscape, drainages/districts,
- Regional unit - urban megalopolises, counties, provinces, states, nation states, nations.

The Cultural/Social Hierarchy scale ranges from individuals and small groups to larger, regional cultural units. As scale increases, number, size, complexity, and diversity increase. Geographic or political location becomes a defining feature as scale increases.

The scales used in the Cultural/Social Hierarchy are "levels of organization", with no implication of levels of importance or power. This structure does not imply, for example, that individuals matter only for the sake of the system. In fact, the holistic ecosystem approach retains the singular human being as an individual component at the lower scale (Ferré 1993). The issues to be addressed will determine what Elements and what scales are selected for analysis, not some value built into the hierarchy itself.

At the smallest scale, the individual — the component level of the human dimension — embodies a mix of genetic factors, but adds to these a unique set of learned social abilities and cultural ideas. Individuals join to form couples, families, and small groups retaining close cultural ties. Because of its relatively limited complexity, this scale maintains the least cultural diversity and little ecosystem analysis has taken place at this scale. Families or small groups are often stable internally, but are most affected by change, with immediate, dramatic effects.

Families and small groups interact to form neighborhoods and communities. At the community level, individuals organize around some unifying trait, common interest, or goal. Community may exist as a society, association, or simply as an aggregation of biologically or socially related individuals that do not necessarily have a specifically defined physical location. A smaller, relatively uniform town, city, or reservation would be considered a community, and so too would the more diffuse "academic community" or "business community". Diversity increases at this level because, while individuals support the community, they still maintain roles that are not part of their community identity. This is where most Forest analyses have taken place, with some analysis at the higher scales.

At the subregional level, larger entities are formed through patterns of interaction and exchange; for example, connections among people to supply

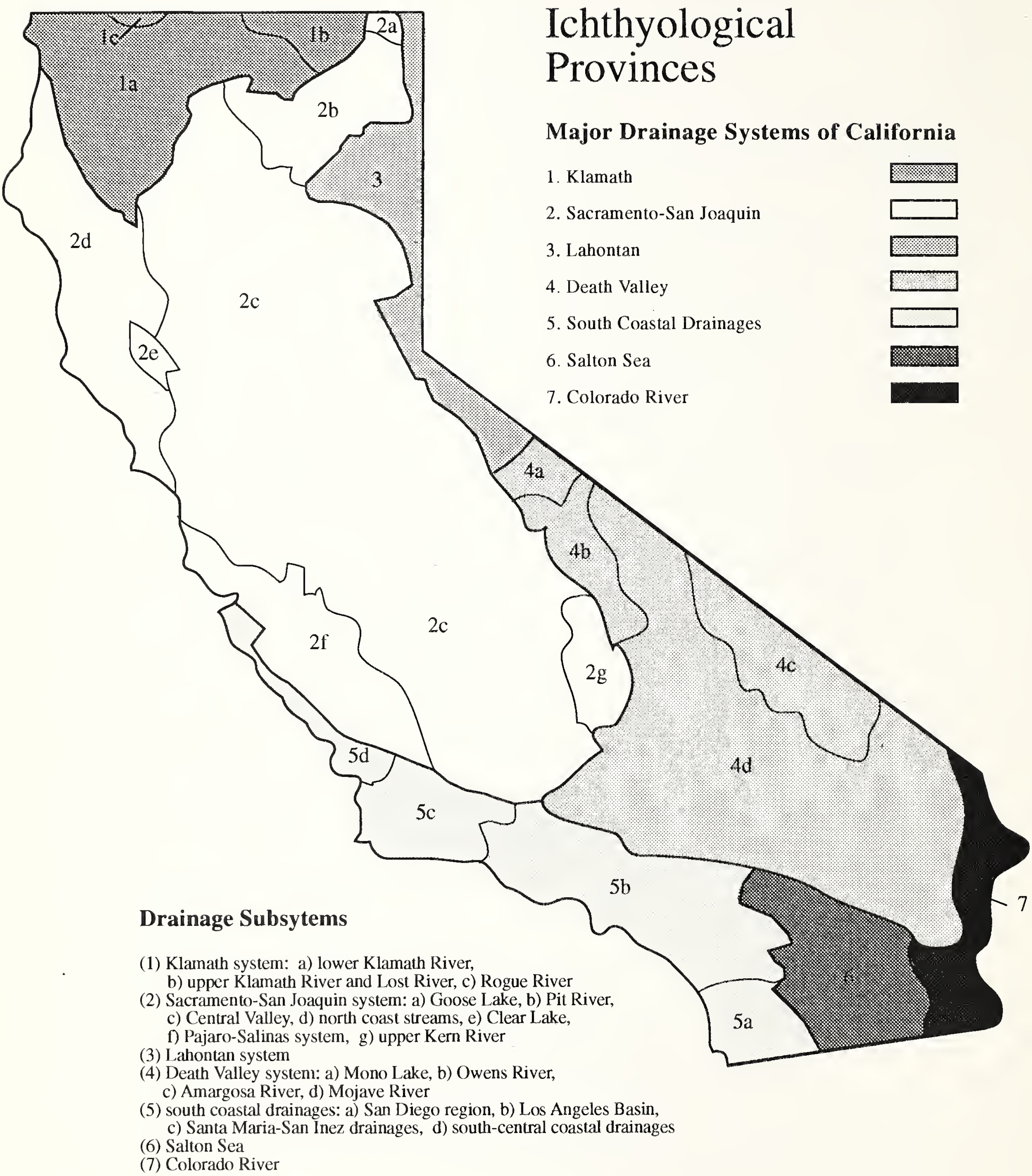

Figure 2-4. Ichthyological province scale and their subsystems (Moyle 1976) as used within the Hydrologic Hierarchy.

Figure 2-5. Air basins within California as defined by the California Air Resources Board.

energy sources and material goods. Geographic or political boundaries may become important defining features, although some cultural elements, such as economic or trade systems, may not have a contiguously defined physical location. Subregions and regions are, by their nature, structures linked by social relationships. At the subregional scale, more diverse combinations of communities and cultural landscapes come together. At this scale, geopolitical units, such as town and city complexes, counties, and larger rural landscapes, may define these units. Drainages may tie communities together by a common water source or provide varying habitats in subsistence cycles of hunting/gathering groups.

At the regional scale, combinations of subregions form large urban megalopolises, counties, states, nation states, and federations (e.g., NATO, United Nations, etc.). Trade, economic, or political patterns dominate at this large and most diverse scale. As we move into an ecosystems approach, more analysis needs to take place at these larger scales.

Individuals or community groups can maintain several roles (e.g., parent/child, employer/employee, etc. at the individual level; police/criminals, businesses/unions at the community or larger level); the nexus between roles is a social relationship. Groups are made up of sets of roles that create social relationships and define social organization for a community or larger scale society. In another example, the role of "central place" that some towns or cities play helps explain the size, number, and distribution of human settlements. These communities function as centers providing goods and services for a surrounding area (Young 1992).

The maps illustrating cultural/social units are a sample of the many possible human activities and characteristics that could be mapped. Here, tribal territories (Figure 2-6) represent possible cultural units, land ownership maps (Figures 2-7 and 2-8) represent possible political boundaries, and population density maps (Figures 2-9 and 2-10) show demographic trends through time. Others will prove useful, depending on the analysis.

Conclusions

Despite the lack of detailed information, we need to "move forward with doubt". Inaction probably presents more risk to us and to the land than using our best stewardship skills to sustain ecosystems. That there will always be things we don't know or understand is unquestionable. Yet we cannot allow this to immobilize us. The management premise has been developed to allow us to move forward while also recognizing the shortfalls of current information on ecosystems.

Implementing coarse-filter/fine-filter biophysical approaches, combined with open-system/closed-system cultural approaches to assess Reference Variability for Environmental Indicators, is the best available approach for maintaining the broad scope of ecosystem components, structures, processes and their functions. As applied, scientific inquiry must also continue to validate the role of individual elements and the linkages among them. Monitoring is essential to provide the necessary information for adaptive management.

Ultimately, management action must result in sustainable ecosystems. Management that maintains and reproduces key components, structures, and processes is most likely to sustain ecosystem integrity and productivity. We will devise Reference Variabilities and Recommended Management Variabilities as the tools we need to exert influence on ecosystems. We must also recognize that restoration of ecosystems to states similar to those prior to contemporary human influences is not always possible nor always desirable. In such cases, sustainability may even be highly dependent upon continued management actions.

Figure 2-6. Tribal territory boundaries in late1880's (Heizer 1978; D'Azevedo 1986).

National Forests in California

Figure 2-7. National Forest System Lands in California.

Figure 2-8. Land ownership within California, as compiled by California Department of Forestry.

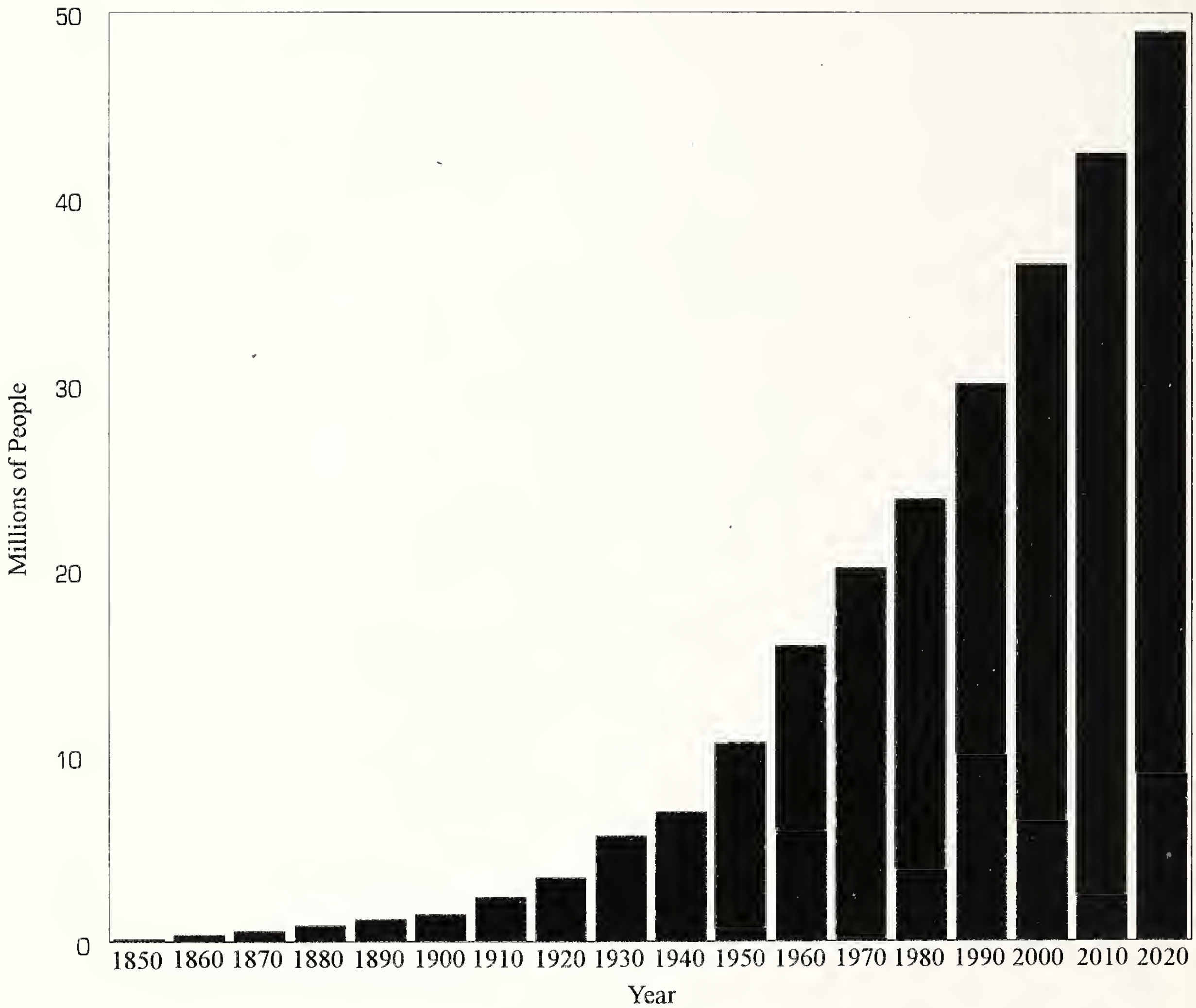

Figure 2-9. California population growth. Population for the years 1850-1990 are actual totals, while those from 2000-2020 are projected. Source: California Department of Finance, 1986: U.S. Census records.

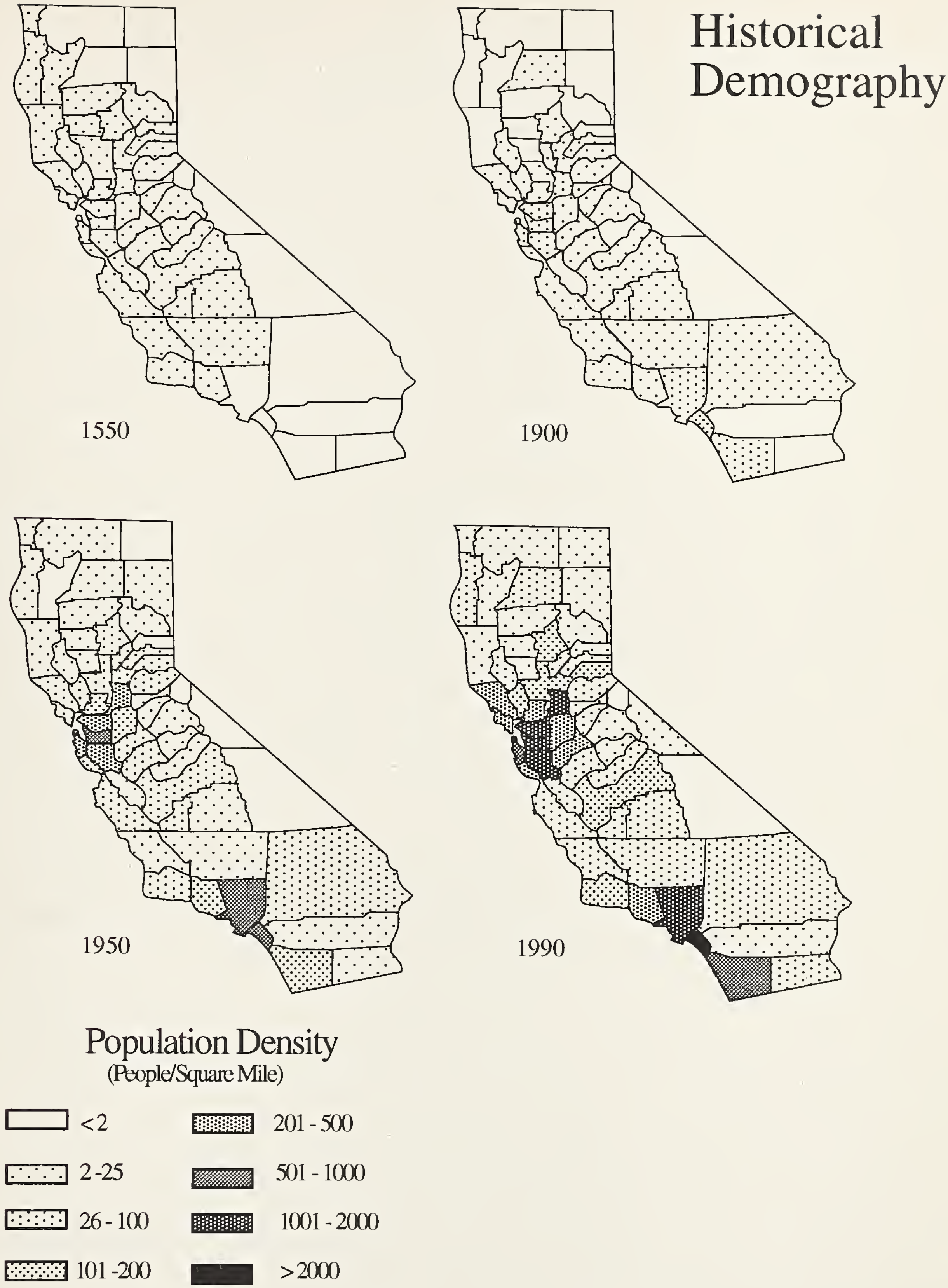

Figure 2-10. Demographic data for population densities in California, adapted from Heizer (1978) and Department of Water Resources (1990).

Chapter 3
Analysis and Planning

Table of Contents

Chapter 3

Table of Contents

continued

Chapter 3

Analysis and Planning

Ecosystem management isn't a thing to do or be involved in,
it is a frame of mind and an approach to work

Anonymous

This Conceptual Framework represents more than just a change in the way we will be doing business. It is a fundamental shift in the way we think about our environment and about the role of people in ecosystems. It fully integrates the physical, biological, and cultural/social dimensions of ecosystems. It will change how we view and interpret past, present, and future environments, and the way we understand the critical scales at which ecosystem processes and functions operate.

Yet, it is not a "cookbook" of tasks to be stepped through to reach a result. Rather, it presents rational thought processes that can be considered to facilitate the integration of ecosystem management concepts into planning.

The essence of the Conceptual Framework is this: **to manage for diverse and sustainable ecosystems, we must maintain and restore the processes and functions under which the ecosystems evolved and to which they are uniquely adapted.** To do this, we must use our best understanding of the biological, physical, and cultural aspects of ecosystem processes and functions over time.

This chapter integrates ecosystem theory, presented in Chapter 2, with analysis and planning. First, in order to develop an understanding of how ecosystems sustain themselves, *analysis* will be discussed. Then *planning* processes will be outlined to show how evaluation, disclosure, implementation, and monitoring contribute to sustaining ecosystems. We will use our existing planning vehicles — the National Environmental Policy Act of 1969 (NEPA) and National Forest Management Act of 1976 (NFMA).

The concepts of *Reference Variability, Recommended Management Variability, and desired condition* are discussed in depth. The heart of the chapter describes ecosystem management implementation at the landscape scale. A brief discussion of analysis at larger scales is also included. The chapter concludes by showing how public participation is integrated within the ecosystem management process.

Conceptual Framework Overview

Implementation of the Conceptual Framework is fairly straightforward. The basis for accomplishing ecosystem management objectives is the formulation of desired conditions across a range of scales.

Analysis is used to gain an understanding of ecosystems, so that the ecosystem itself is the context for management actions. The Conceptual Framework uses a process that focuses on those aspects of an ecosystem that drive sustainability. This analysis process is illustrated in Figure 3-1.

Planning processes are used to define desired condition for an area after full consideration of Recommended Management Variability for the Environmental Indicators. Comparison of an area's

ECOSYSTEMS

↓

Ecosystem Elements

↓

Key Ecosystem Elements

↓

Environmental Indicators

↓

Reference Variabilities

↓

Recommended Management Variabilities

↓

Input to Desired Condition

Figure 3-1. Generalized ecosystem analysis process. This flowchart illustrates the steps necessary to move from a broad description of an ecosystem to a more specific definition of desired condition.

desired condition to its *existing condition* identifies opportunities for action. The opportunities, in turn, are used to develop the kinds of projects that would cumulatively maintain desired conditions or move an area toward them. The process is summarized in Table 3-1.

Desired condition is the cornerstone for achieving physical, biological and cultural/social objectives for ecosystem management and is thus expanded upon below. The development of desired conditions will occur for specified analysis areas at a variety of scales, including those that cross Forest and jurisdictional boundaries. Desired condition descriptions that arise from ecosystem management analyses reside in the Regional Guide and Forest Plans.

Actual application of analysis and planning concepts may be confounded by a lack of desired historical or reference data for some physical, biological, and cultural/social Environmental Indicators. There will be data needs that cannot be met, but the process will still work with partial information and best professional estimations.

Fundamentals of the Analysis Process

The ecosystem analysis process is based on long standing methodologies that incorporate the scientific method. What follows is a discussion of the various aspects of the analysis process.

Table 3-1. Five questions illustrating the analysis and planning process.

QUESTION	PRODUCT
How did ecosystems evolve?	Reference Variability
What is sustainable?	Recommended Management Variability
What do we want?	Desired Condition
What do we have?	Existing Condition
How do we get there?	A suite or sequence of site-specific projects

Establishing the Context for Ecosystem Analysis

Perhaps the greatest shift in our management of National Forests is that we are focusing on issues and concerns relevant to larger spatial and temporal scales (e.g., species viability), and relevant ecological and socio-cultural structures and processes operating at these scales. It is clear that many processes operate at larger scales than those of Districts or National Forests and the communities that surround them. Unless we first establish the appropriate context, we risk pursuing ecosystem analysis without clear goals and objectives.

Examples of work that provide a context and identify larger scale issues are the President's Forest Plan (USDA et al. 1994) and associated River Basin-Watershed Analysis process, the PacFish Environmental Assessment, the California Spotted Owl Interim Guidelines Environmental Assessment (CASPO), the Regional Guide, and Forest Plans. Future large scale planning may set the context for regional issues that will also drive ecosystem analysis and management.

Ecosystem Hierarchies

While no one ecosystem hierarchy captures all the different processes and functions, the use of hierarchies is important to the analysis process. Two closely linked questions will arise in the analysis process when trying to select from among the four hierarchies (presented in Chapter 2):

- Which ecosystem hierarchy(s) would be most appropriate to define the analysis area?
- What scale of analysis will best relate to the concerns or questions driving the analysis?

Any given ecosystem analysis area may incorporate facets of each of the four hierarchical systems. One may need to analyze ecosystem processes at a larger scale for each of the selected hierarchical systems before addressing critical processes and patterns operating at the smaller scale of the analysis area. For example, to analyze aquatic species viability within a watershed, one will first need information at the relevant larger scale — say, the Ichthyological Province in the Hydrologic Ecosystem Hierarchy.

This need to look at larger scales first is particularly true for cultural/social analysis which operates within widely differing boundaries and gradients. For example, analysis at the community level often cannot take place without knowing more about the larger subregional or regional scales.

Information obtained and organized according to the four ecosystem hierarchies can be combined or split as needed to focus on relevant issues and concerns (USDA 1993). This data aggregation can be accomplished by overlaying the selected hierarchical scales on the ecosystem and using information from those units that fall within the analysis area.

How do analysis and planning actions relate to the hierarchical system scales? Table 3-2 displays the various analysis scales and associated possible planning actions.

Ecosystem Elements and Their Measures

Ecosystem Elements

Ecosystems can be described in terms of their components, structures, and processes. These three types of *Ecosystem Elements* form the defining attributes of any ecosystem. Tables 3-3 and 3-4 list the Ecosystem Elements for the four hierarchies. These lists are not all inclusive.

Key Ecosystem Elements

Infinite time and money would allow us to model our ecosystems using every conceivable element. Since both of these factors are limiting, we must identify and select a few elements that best **represent** a given ecosystem. We cannot use them all.

Table 3-2. Analysis scales and their relationship to associated planning actions.

Scale[1]	Probable Planning Units	Possible Planning Actions	Possible Products
Land Unit Up to 100s of acres	Forest; Ranger District	NEPA compliance; project implementation, monitoring, and evaluation	Projects (NEPA documents); Accomplishment reports
Landscape 100s to 1,000s of acres	Multi-Forest; Forest; Ranger District	Recommended Management Variability Analyses; Desired condition determination; NFMA analyses	Management Area direction; Implementation schedules
Subregion 10s to 1,000s of square miles	Region; Multi-Forest; Forest	Inter/intra-agency Recommended Management Variability analyses; Desired condition determination; NEPA & NFMA compliance; Subregion analysis†	Subregion guides; Forest Plans; Forest Plan Amendments; Multiple Forest Plan Amendments
Ecoregion 10,000s to 1,000,000s of square miles	Multi-Region; Region; Multi-Forest	Inter/intra-agency Recommended Management Variability analyses; Broad determination of desired condition; NEPA and NFMA compliance; Ecoregion analysis[2]	Regional Guide; Ecoregion guides; Multiple Forest Plan Amendments

[1] From USDA. 1993. National hierarchical framework of ecological units. Forest Service. Washington, D.C.
[2] Ecoregion and Subregion analysis may be used as input to amend multiple Forest plans.

Key Ecosystem Elements are a distinct subset of Ecosystem Elements. They are the elements over which management and society have an influence. For example, we do not influence elements like geological processes or climate. Those elements affected by humans are good candidates for analysis and monitoring. To better identify and track such Key Ecosystem Elements, they are categorized by the four different ecosystem hierarchies presented in Chapter 2 (Table 3-3). They form the basis for evaluating the effects of management on ecosystem sustainability.

Several elements of the Cultural/Social Hierarchy are not shown above because they have been subsumed under one or more of the other Key Elements presented. For ease of analysis, information flow is tracked within the social organization and material culture elements. Within these elements, networks and technology facilitate information flow. Additionally, migration has been assimilated within the land use and settlement patterns and population characteristic elements, where patterns, networks, and temporal trends reflect change.

Elements that people cannot change, or those that change slowly with or without their influence, are not ideal for analysis nor monitoring. These elements are, however, worthy of recognition due to

Table 3-3. Key Ecosystem Elements that are influenced by people and are measurable. This is not an all inclusive list.

	Hierarchies			
	Terrestrial	Hydrologic	Atmospheric	Cultural/Social
Components	Animal species Plant species Food webs Insects Organic debris Genetic diversity Pathogens and Disease	Animal species Riparian and aquatic plant species Food webs Channel morphology Genetic diversity Water Sediment Organic debris	Ozone Sulfur dioxide Nitrogen oxides Particulates	Attitudes, beliefs, and values Lifestyles and lifeways Material culture
Structures	Vegetation mosaic Food web Genetic diversity Organic debris	Channel morphology Sediment Water Genetic diversity Organic debris Riparian and aquatic plant species Food Web		Social organization Lifestyles and lifeways Land use and settlement patterns Population characteristics Material culture
Processes	Fire Nutrient cycle Soil productivity Insects Pathogens and Disease Soil hydrologic function	Nutrient cycle Hydrologic cycle Fire Erosion Genetic diversity	Fire Nutrient cycle Hydrologic cycle	Economics and subsistence Invention and diffusion

the direct or indirect effect they may have on Key Ecosystem Elements, mentioned above, and overall ecosystem function. Table 3-4 lists some of these elements. The Cultural/Social Hierarchy is not included in Table 3-4 since all of its elements are subject to change by people.

Environmental Indicators

Environmental Indicators are the various ways to measure each Key Ecosystem Element. For example, fire as a Key Ecosystem Element can be measured at the landscape scale in terms of the following Environmental Indicators: severity, size, distribution, return rate, or seasonality. Furthermore, each Indicator will have one or more units of measure. Fire size as an Environmental Indicator can be measured in square feet, square meters, acres, hectares, square miles, etc.

The selection of Environmental Indicators depends on the scale of the analysis and on the questions being considered. To illustrate how Environmental Indicators can vary over spatial scales and to show which Indicator is relevant or appropriate, matrices were developed to facilitate the selection process. They are located in Appendix A. These matrices list Environmental Indicators for each element at the various scales.

Table 3-4. Ecosystem elements over which people have a limited influence.

Ecosystem Elements	Hierarchies: Terrestrial	Hydrologic	Atmospheric
Components	Geology Soil series	Geology Soil series	Oxygen Moisture
Structures	Topography Geologic structure	Topography Geologic structure	Barometric pressure gradients
Processes	Climate Weather (local) Geomorphic processes	Hydrologic cycle Climate Weather (local)	Climate Weather (local) Airflow pattern influences

The same Environmental Indicators should be used and tracked throughout ecosystem management analysis and planning to:

- provide the basis for Reference Variability,
- provide the basis for Recommended Management Variability,
- quantify desired condition,
- assess the impacts of proposed projects in the NEPA process,
- test the validity of selected Key Ecosystem Elements in reflecting ecosystem processes and links, and
- see if an area is moving toward desired condition.

Reference Variability and Recommended Management Variability

The concepts of Reference Variability and Recommended Management Variability for Environmental Indicators of Key Ecosystem Elements play a major role in developing a desired condition.

The use of Reference Variability is based on this premise: **ecosystems adapted over extended time periods, in total, present the best chance for sustainability through the future; and management designed to maintain or reproduce key components, structures, and processes is the most likely management approach to sustain ecosystem integrity and productivity.**

Key Ecosystem Elements and Environmental Indicators chosen for a specified area should be of both biophysical and cultural/social origin, although the two may not always be easily separable. They will determine the Reference Variabilities for the area. Management within the Reference Variabilities for Environmental Indicators is assumed to restore and maintain biological diversity and ecosystem integrity. The subset of Reference Variability, known as Recommended Management Variability, further defines a set of conditions that present less risk to ecosystem stability and resiliency.

Defining Reference Variability and Recommended Management Variability discloses ecologically important information, leading to better informed decisions. When the Forest Service considers managing outside Recommended Management Variability, it should disclose the potential consequences.

Determination of Reference Variability and Recommended Management Variability

How should Reference Variability and Recommended Management Variability be determined? If we had complete, long-term data for a particular Environmental Indicator, Reference Variability could be displayed by graphing Environmental Indicator values and their corresponding frequencies. The results would likely resemble a bell shaped or inverse J-shaped curve (Figure 3-2). The tails of the curve (shaded areas) represent infrequent, more extreme values. These values probably result from more extreme disturbance events that would most likely occur regardless of our management. Such events carry the risk of surpassing limits of system stability or resiliency.

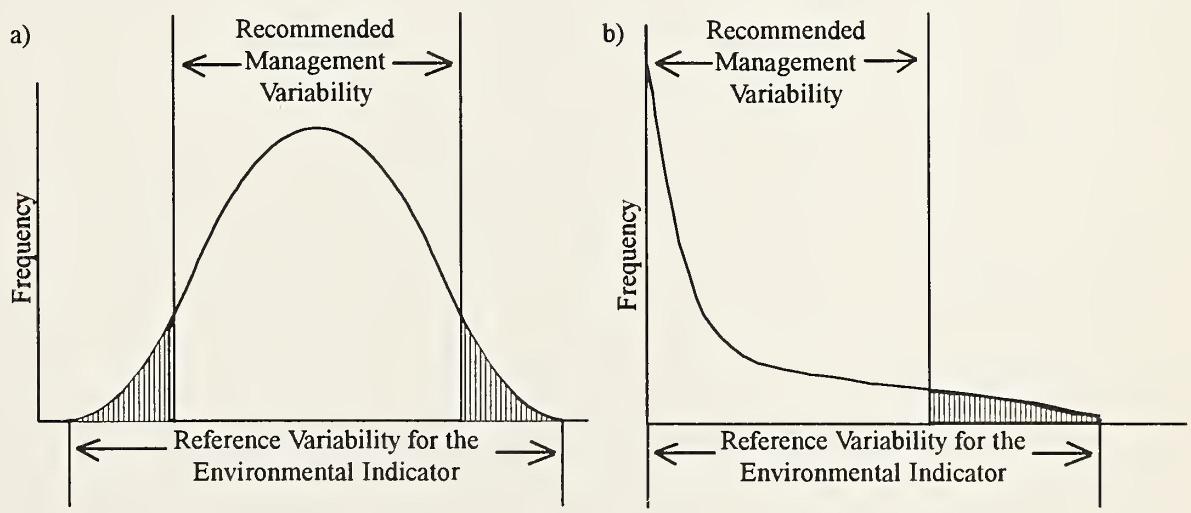

Figure 3-2. Distribution of values for two different Environmental Indicators over time. The shaded areas indicate infrequent occurrence at the extreme ends of each Reference Variability. a) a normal distribution, b) an inverse J-shaped distribution.

Interaction of extremes for two or more Environmental Indicators may produce results outside the Reference Variability for the ecosystem as a whole. For example, simultaneous management of a faunal species population at the low extreme of its Reference Variability and fire occurrence at the upper extreme of its Reference Variabilities for size and intensity, could eliminate the species. Or, a community economy based on a single industry and impacted by an extreme event could eventually collapse.

The entire distribution of Reference Variability is important and should be realized over long-term, evolutionary time scales. Planned management activities should not normally seek to replicate extreme values of the range, since they will occur naturally.

The entire distribution of Recommended Management Variability is also important for ecosystem sustainability. Management strategies implementing desired condition should facilitate variation within Recommended Management Variabilities over time. Figure 3-3 illustrates how the value of an Environmental Indicator would, ideally, vary over time, with the occasional occurrence of major disturbance events that move the Indicator outside Recommended Management Variability to the extremes of the Reference Variability.

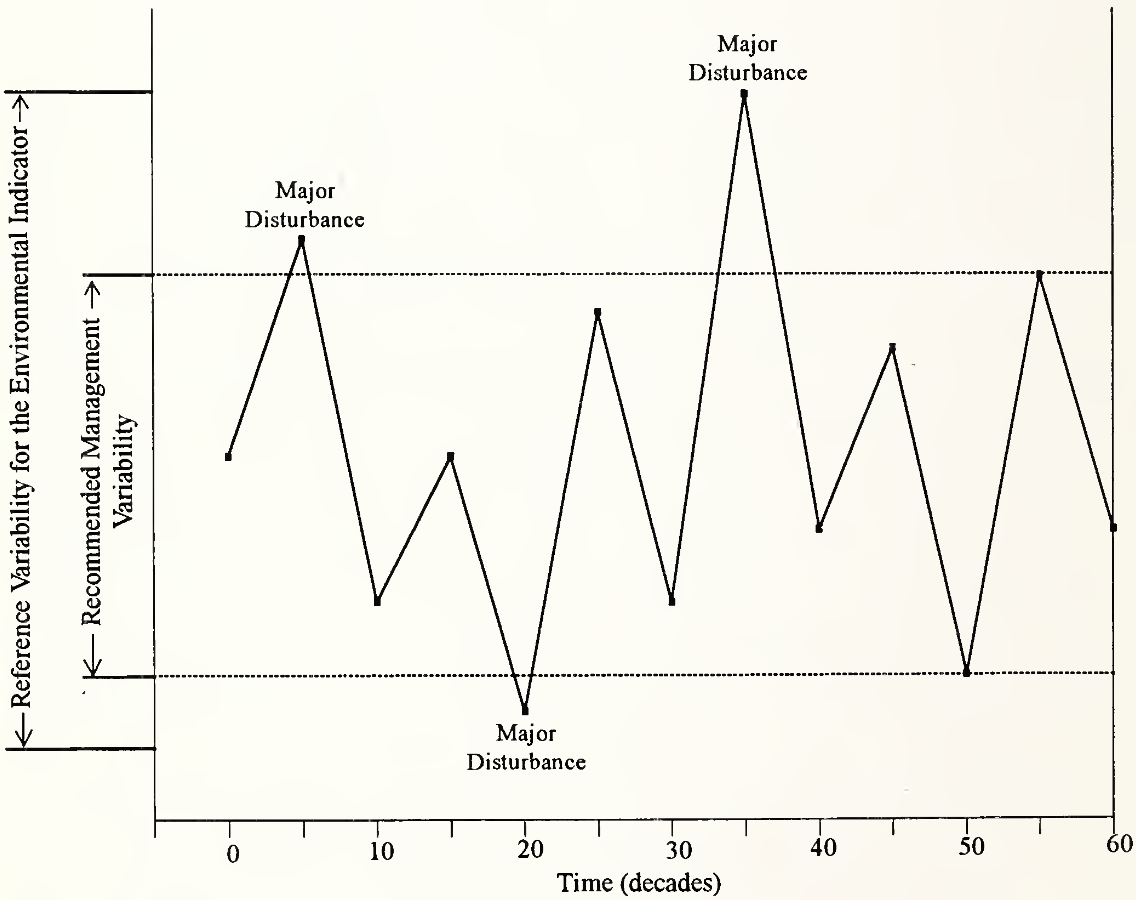

Figure 3-3. An Environmental Indicator's characteristics over 600 years. The distribution shows the magnitude and timing of events within the Reference Variability. Recommended Management Variability occurs within the range of more frequent events and excludes major disturbances.

Management within Recommended Management Variability may affect the occurrence of more extreme Reference Variability events. For example, the occurrence of frequent, less intense fires may reduce the likelihood of a large, intense fire that could severely impact the stability or resiliency of the system. In other types of events, such as floods, such a relationship is less clear but the risk of managing to mimic extreme events is still apparent.

Figure 3-2 displayed the relationship between Recommended Management Variability and Reference Variability. Where the lines are drawn for Recommended Management Variability is not a straightforward matter. In most cases, complete data to determine Reference Variability will be lacking; this compounds the difficulty when defining Recommended Management Variability.
Not only will determining the Recommended Management Variability limits be difficult, but the frequency curve relationship itself is not likely to be well defined. For many Indicators, it is likely that historic data will show relatively few points in time, so the entire range, distribution, and frequency of values over time and space will not be fully known. Consideration of the limitations of the data set, outlier points, and best professional judgment will be key in determining Recommended Management Variabilities. They will be benchmarks for our analyses.

The Relationship Among Reference Variability, Recommended Management Variability, and Desired Condition

How do the concepts of Reference Variability, Recommended Management Variability, and desired condition relate to one another? We know that:

- Recommended Management Variability is equivalent to, or a subset of, Reference Variability;
- existing condition may or may not lie within the distributions of Reference Variability or Recommended Management Variability values; and
- the chosen desired condition may not be able to accommodate every Recommended Management Variability.

Graphical illustrations of these concepts may create a better understanding of their relationships. Below are three example scenarios that are provided for discussion purposes. The desired condition for each scenario would be a composite description of the various selected Environmental Indicators and their respective units of measure, therefore, each Indicator will have unique desired condition values. For simplicity, only two to three Environmental Indicators are displayed.

Scenario 1

A District wishes to restore a more natural fire regime to a subwatershed with a very short fire return interval (e.g., < 10 years) through prescribed burning (Figure 3-4). Although much longer periods between fires have occurred historically, there is evidence that when the area does burn after a long period, high sedimentation levels result in the creek. Economics and logistics would make it very difficult to reproduce return intervals at the lower end of the Reference Variability range (e.g., every 2 - 3 years).

Scenario 2

Introduced trout have dramatically reduced the population of native frogs in a natural lake within the landscape under analysis (Figure 3-5). Historically, the frogs were plentiful and native trout were nonexistent (over the past several thousand years). Many people have hiked into the lake annually over the last decade and the majority have enjoyed fishing as a part of their recreational experience. After consulting with the U.S. Fish and Wildlife

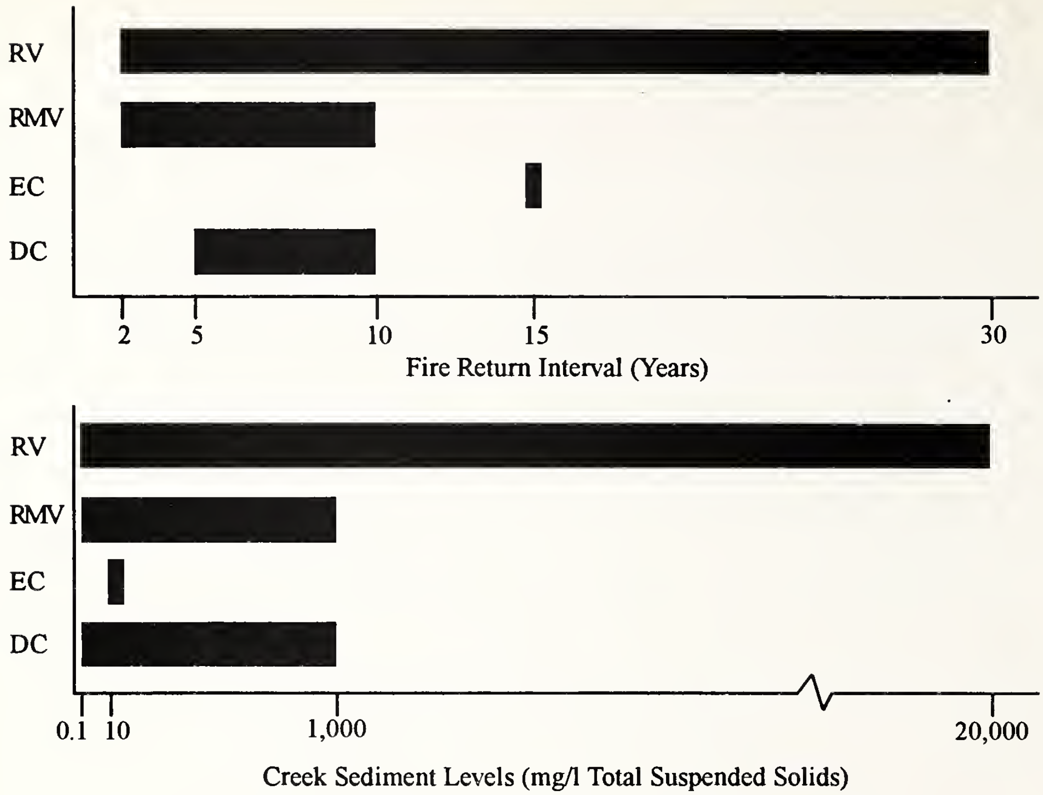

Figure 3-4. Fire regime and sediment loading scenario. Economic and logistic constraints confined the desired condition (DC) to a portion of the Recommended Management Variability (RMV) for fire return interval where the interval is longer (i.e., 5 - 10 years). To maintain water quality, the desired condition for creek sediment load levels is equal to Recommended Management Variability. (RV = Reference Variability; EC = existing condition).

Service and considering the tradeoffs involved, the selected desired condition was to continue providing recreational fishing opportunities in the area, while providing refuge habitat for the frog to lessen the impacts of predation and allow the species to repopulate the lake. Other areas, outside the landscape of analysis, may be used to provide suitable habitat for the frog species to maintain viability.

Scenario 3

People have traditionally gathered a certain plant species which has become relatively rare within the analysis area. Species viability is questionable due to many factors such as fluctuating rainfall patterns, encroachment of tree seedlings, loss of habitat outside the analysis area, and the rising popularity of gathering. After considering the tradeoffs involved, the selected desired condition was to prohibit gathering of the plant within the analysis area and carry out projects to encourage restoration of the species' historic population level.

Reassessment of Recommended Management Variability

Reassessment of Reference Variabilities and Recommended Management Variabilities, and perhaps even the Environmental Indicators used, may be necessary from time to time. This could also lead to modification of desired conditions under an adaptive management approach.
As new information becomes available, ideas

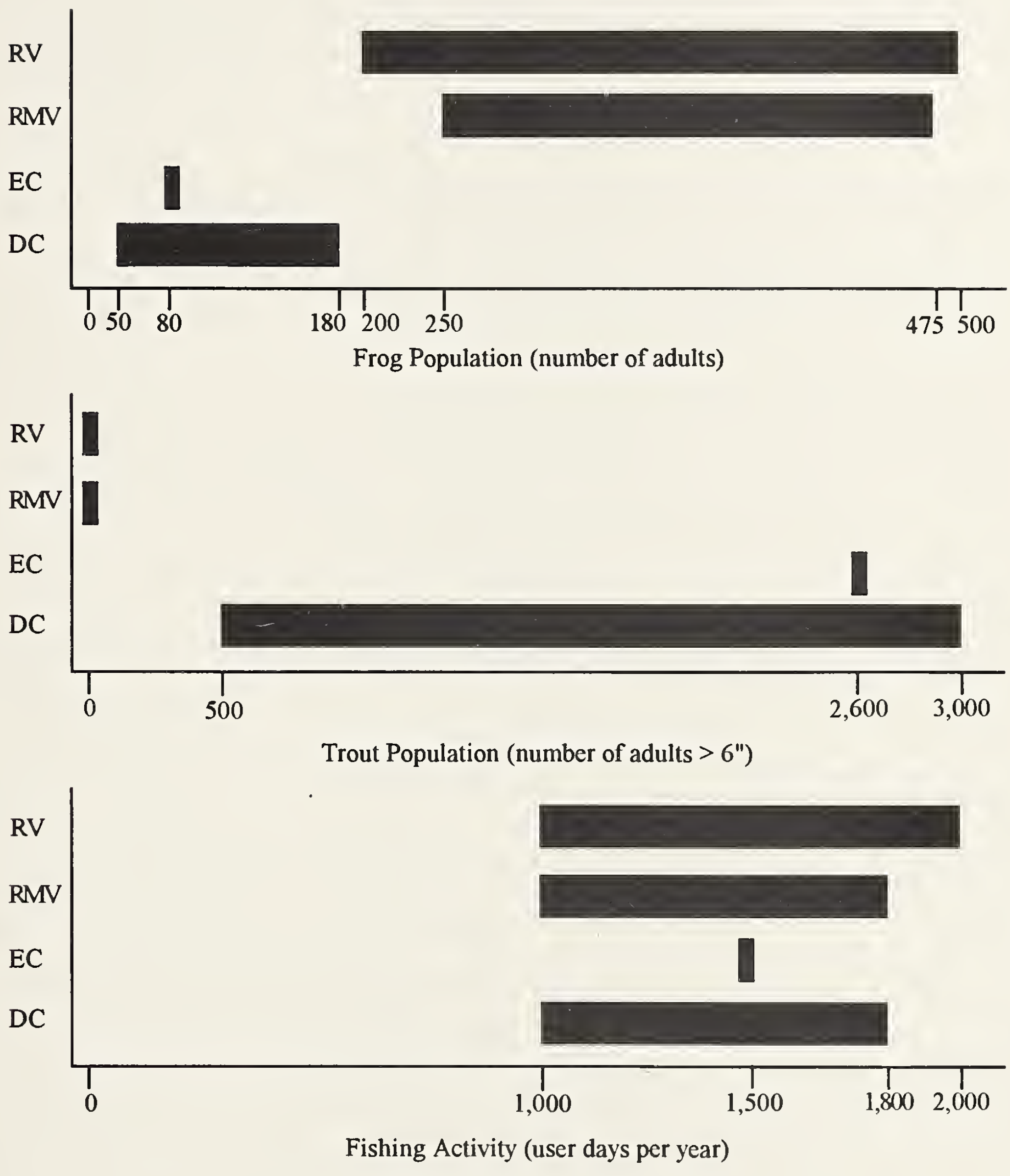

Figure 3-5. Introduced trout and native frog population scenario. Not all Recommended Management Variabilities (RMV) could be met--either fish stocking would be maintained or historic frog population levels could be restored. Reference Variability (RV) and Recommended Management Variability for trout represent populations present prior to 1900. Because trout and frogs do not always coexist, a choice had to be made in determining the desired condition (DC). (EC = existing condition).

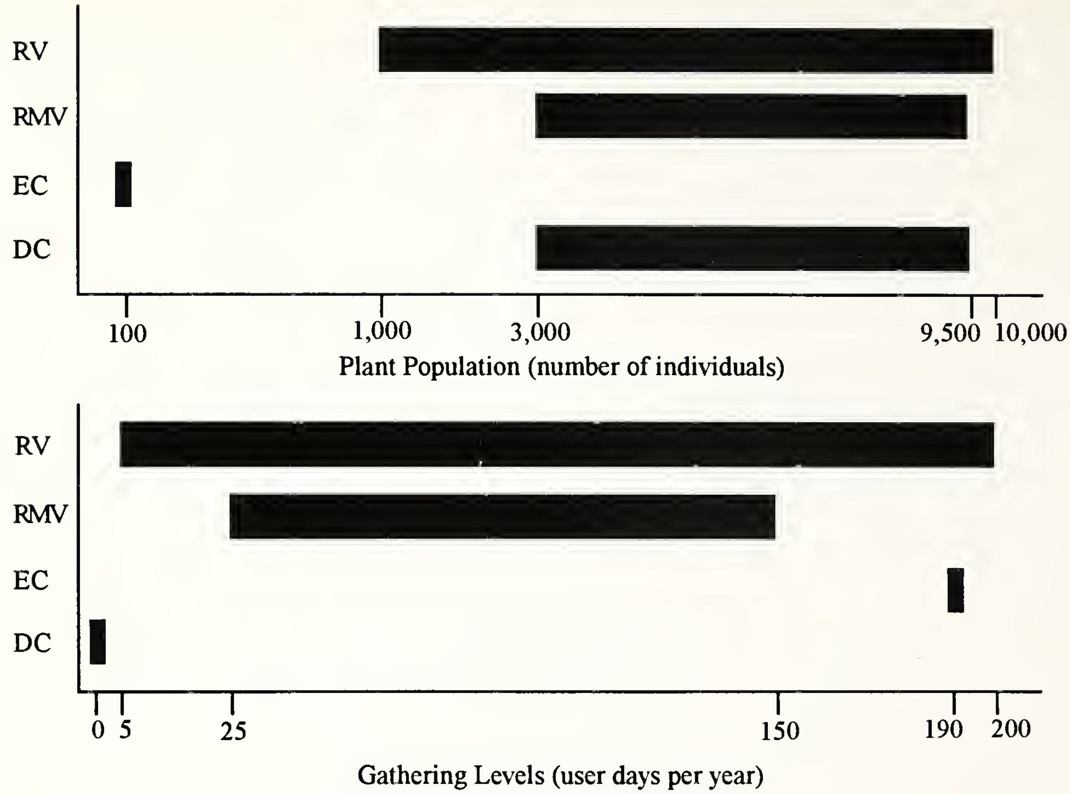

Figure 3-6. Plant population and gathering scenario. Not all Recommended Management Variabilities could be met--either gathering use would be maintained or plant populations could be restored. A choice had to be made in determining the desired condition. (RV = Reference Variability; EC = existing condition)

regarding the appropriate Environmental Indicators to use (or more accurate estimates of Reference Variabilities and Recommended Management Variabilities) may be possible. Conceptually, Reference Variability and Recommended Management Variability would not change significantly over ecological time frames. However, we expect that our estimates of them will change as scientific findings enhance the data upon which we base our estimates.

Major environmental disturbance could provide impetus for reassessment. Disturbance may provide information that defines more accurately Reference Variabilities and Recommended Management Variabilities. The disturbance may have changed the ecosystem so that the original desired condition is no longer a realistic, long-term goal — it is a "new" ecosystem brought about by an extreme disturbance that has pushed the old system beyond its limits of stability and resilience.

Managing Outside Recommended Management Variability

The goal is for most National Forest landscapes to exist within the Recommended Management Variability for a chosen set of Environmental Indicators, as this is our best option for maintaining diversity and ecosystem sustainability. However, there are, and will continue to be, landscapes in which various desires from the three dimensions of ecosystems cannot be mutually accommodated. The desired condition for some landscapes may not describe the established Recommended Management Variability, and may even be outside of

Reference Variability. Examples include ecosystems impacted by dams, buildings, utility corridors, ski areas, and perhaps even requirements for listed plants and animals. The influence of urban interfaces on wildland landscapes will also challenge forest managers, because a desire to stay within Recommended Management Variabilities may have to be tempered by the need to protect life and property.

Being outside Recommended Management Variability for one or more Environmental Indicators does not necessarily mean that the ecosystem is unsustainable. It is a "red-flag" that indicates a potential increased risk to sustainability, and a need for analysis and justification of the selected desired condition.

Desired Condition

What is Desired Condition?

Desired condition is the focal point of ecosystem management implementation. It is a strategic decision that guides subsequent management actions. So what exactly is desired condition?

Desired condition (formerly known as desired future condition) is not a new planning concept. As early as 1982, Forest Service planning regulations called for descriptions of desired conditions in the development of Forest Plan goals and objectives [36 CFR 219.11(b)].

In its basic formulation, *desired condition* is the decision space bounded by physical, biological, and cultural/social considerations. This concept is illustrated in Figure 3-7. Implicit in the diagram is that the three dimensions of an ecosystem act upon one another. Environmental Indicators provide meaningful measures of system components, structures, and processes.

Describing Desired Condition

Desired condition is an integrated, pragmatic expression of the state or condition in which we prefer our ecosystems to exist, now and into the future. Ideally, it reflects a distribution of conditions, recognizing that landscapes cannot be "frozen in time". Some desired conditions may be long-term goals — mature seral stages, for example — which may not be realized for several decades or longer. It is important that the desired condition not be unduly influenced by existing condition. This is to prevent the desired condition from merely being a description of the status quo. However, desired conditions must remain within the inherent capabilities of the land.

Descriptions of desired condition primarily address the land and its associated resources, including human values. While most aspects of the physical and biological dimensions of an ecosystem are easily expressed in terms of land and resource condition, the cultural/social dimension is a greater challenge. Cultural/social elements (i.e., social organization, lifeways, attitudes, values, etc.) influence the development of desired condition, and are usually "translated" from the abstract realm into physical descriptions of land and resource states to give both a common denominator. The Forest Service does not provide "recreational experiences"; rather, it provides a spectrum of settings in which people have the opportunity to enjoy a variety of recreational experiences. Thus, we directly manage the physical settings (soils, vegetation, access, and infrastructure), expecting indirect effects: visitor satisfaction, challenge, and spiritual renewal.

Desired conditions are typically described in terms of selected Key Ecosystem Elements, as measured by Environmental Indicators, preferably as quantified values. As a composite of various considerations, desired condition is a multidimensional product.

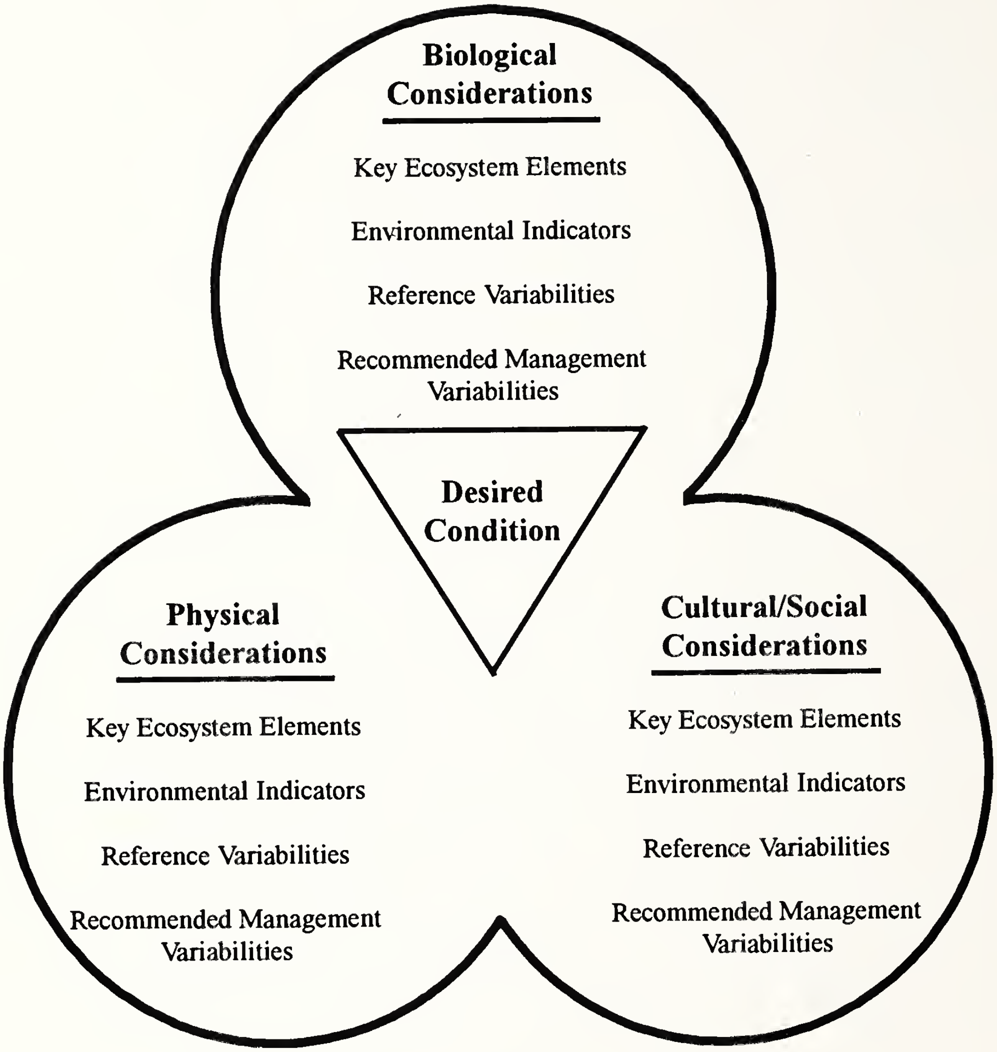

Figure 3-7. Integrating ecosystem dimensions to determine desired condition. At each relevant scale, physical, biological, and cultural/social Elements and their Indicators are considered to derive a desired condition.

Desired Condition and Planning Documents

From what sources are desired conditions derived? In accordance with NFMA, a Regional Guide is prepared for each region, while Forest Plans are developed for each National Forest unit. These two planning documents provide a hierarchy of desired conditions.

The Forest Plan's multiple-use goals and objectives provide the basis for desired condition over the entire Forest and Management Areas within the forest. At the Forest scale, desired condition is the visualization of the condition of the Forest after full (and successful) implementation of its Forest Plan. As a product of the NFMA/NEPA processes, desired condition development must include public participation. Management's prerogative to adopt a desired condition becomes a "contract" between the Forest Service and the public.

One apparent paradox needs to be reconciled: desired condition is derived from our Regional Guide and Forest Plans — yet most of these documents were not explicitly developed using an ecosystem management approach. The resolution of this paradox is for land managers to use the inherent flexibility in these documents to allow further refinement and adjustment of desired condition within the bounds of existing Plans. In the longer term, managers need to start applying the Conceptual Framework to bring the Plans in line as quickly as possible. Ecosystem management analyses, and any resulting Plan amendments or revisions, need to consider desired condition at relevant scales. This process requires an assessment of ecosystem conditions beyond the Forest boundary. Later in this chapter we will see how desired conditions may be formulated and added to an existing Forest Plan.

Formulating desired condition through a range of scales triggers two important needs. First, we need an administrative mechanism to collect and analyze data at scales not often considered in Forest-level planning (e.g., subregion, ecoregion). Second, we need to document these desired conditions and associated analyses. Table 3-2 displayed some "products" of analyses and desired conditions at three of the four analysis scales. The land unit scale is generally too small to have a desired condition.

For desired condition to be readily available and retrievable, it must reside in the products of planning: the Regional Guide or individual Forest Plans. The supporting documentation of the various analyses need to be maintained in the planning records.

Example of a Desired Condition

What might a desired condition description look like? Traditional descriptions of desired condition have typically been qualitative narratives using somewhat subjective (or undefined) terms such as "good" or "acceptable". Under the ecosystem management process described here, desired condition descriptions should include **quantitative** characteristics of land condition based on Environmental Indicators. An example of a desired condition is provided in Box 3-1. This example of a desired condition narrative includes quantifiable measures. The present tense is used here to describe the future condition in accordance with Land Management Planning conventional usage.

Box 3-1. Example of a desired condition described by quantitative measures.

The landscape is a 100,000 acre watershed in the eastern Sierra/Cascades. Substantial winter snowpacks support several perennial streams that drain the area. The topography is relatively gentle. The wetter valley bottoms usually support meadows, while the dryer valleys are dominated by sagebrush. Most of the landscape is in federal ownership except for a few cattle ranches. The geology is a granitic batholith intruded by volcanics. The desired condition for the landscape is described below.

Aquatic: All of the streams in this landscape have been inventoried and classified. Overall habitat quality is considered good to excellent. Aquatic habitat improvement work primarily consists of maintaining and/or replacing existing structures. For three of the selected Environmental Indicators (width /depth ratio, temperature, and substrate) of habitat quality, the desired condition is described below.

Stream Type	Width/Depth Ratio	Temperature	Substrate Ratio
Confined	1:1 - 2:1	max 50 - 55	cobble/boulder
Unconfined	2:1 - 3:1	max 52 - 60	gravel/cobble/boulder
Alluvial	2:1 - 4:1	max 55 - 65	sand/pebble/gravel

Fire: The Jeffrey pine and meadow vegetation types are sustained by fire, the primary landscape-scale disturbance regime operating in the watershed. Others include flood and drought-related insect infestations. Fire keeps fuel loading low, eliminates encroachment of pines and sagebrush into meadows, and maintains the grass/forb component in the forest understory. In addition, it regulates stand structure through understory thinning and snag recruitment. The desired conditions for fire indicators are shown below.

Return rate: 5 - 20 years

Severity	Seasonality
60 - 95% low	1 - 7% spring
24 - 40% moderate	1 - 10% summer
5 - 20% high	75 - 95% fall
0 - 5% extreme	

Box 3-1. continued

Heritage: The entire landscape has been inventoried, and properties eligible to the National Register of Historic Places have been identified. Those with potential for addressing research questions important in regional prehistory and history, including ecosystem management, are being studied for the information which they can reveal. Those with values contributing to Forest interpretive themes are being developed and interpreted to the public , and are being studied/monitored for visitation impacts. Those with preservation needs to prevent deterioration or impacts from human use, vandalism, or looting are being studied/ monitored and stabilized, as needed. Desired condition is described below.

Site value	Vandalism Incidents	Deterioration	PAOT's/Visits	Research
Research Value	0	0 - 5%	N/A	1 research study /yr
Interpretive Value	0	0 - 10%	25/2500	1 visitation study/yr
Protection Needs	0	0 - 5%	N/A	1 vandalism study/yr

Land ownership: The four parcels of private land containing meadow and riparian habitat, previously identified as high priority for acquisition, are now National Forest System lands. No further land ownership adjustments or consolidations are desired.

Recreation: As verified by scheduled visitor surveys, the landscape provides a high quality experience for persons seeking dispersed recreation opportunities. A Recreation Opportunity Spectrum (ROS) setting of semi-primitive motorized (SPM) with a landscape condition meeting the Adopted Visual Quality Objective (AVQO) of partial retention (PR) describes this desired condition. Through the use of education, recreationists are camping within 50 feet of system roads. The need for patrolling by Forest Service officials is minimal. The desired density of dispersed campsites ranges from 2 to 7 sites per square mile. During the winter months, a system of cross-country ski trails is operated and maintained through partnerships. Opportunities identified in the Forest interpretive plan are developed.

Roads: All roads needed for resource management have been constructed. Unnecessary roads have been completely rehabilitated to restore site productivity. Signing and education has eliminated the routes formerly created by unauthorized motor vehicle use. The total road density for the landscape is 1.4 miles per square mile, of which 0.75 to 1.25 miles are open at any one time.

Vegetative Condition: The landscape is dominated by a continuous forest of Jeffrey pine, interspersed with meadows and sagebrush flats. The forest exhibits open-grown or "parklike" characteristics; light reaching the forest floor supports a grass/forb component. The forest normally has only one layer. Riparian areas and some north-facing slopes may have multiple canopy layers. The two Environmental Indicators selected here are: total acreage of vegetation types; and proportion of the landscape in various seral stages.
The overall mix of types of potential natural vegetation within the entire landscape ranges are listed below.

Non-vegetated	Grass/Forb	Jeffrey pine	Riparian
5%	20%	70%	5%

The Jeffrey pine forest structure trends toward a mature appearance. Patches of varying size (20 to 120 acres) are distributed across the landscape. Changes in structure between patches are gradual rather than abrupt. Corridors connecting patches of old growth forest are evident. The desired mix of seral stages in the Jeffrey pine type is shown below.

Shrub/Forb	Pole	Early Mature	Mid-Mature	Old Growth
0 - 10%	15 - 25%	15 - 35%	15 - 40%	20 - 30%

Wildlife: The ensatina salamander is one of the Environmental Indicators for the animal species element in this landscape. The primary habitat of ensatina salamander is large downed woody debris. They require uncompacted soils for excavation and woody debris for cover and foraging. Soil should not be compacted to reduce porosity more than 10%, as compared to adjacent, undisturbed soils. The desired condition for the ensatina salamander is shown below.

Population Size	Logs < 10" diameter	Soil Compaction
1000 - 1500	4 - 8/acre	< 10% of habitat area

A note on scale: The desired condition described above was not analyzed in isolation. The analysis leading to this desired condition would have also addressed these same Environmental Indicators at the land unit scale (one scale down) and the subregion scale (one scale up).

Implementation at the Landscape Scale

Most resource specialists work at the District or Forest level, and will do analysis at the landscape or similar scales. Thus, the following is a conceptual "cradle to grave" description of how one might approach such analysis and planning activities.

The landscape analysis process outlined below is illustrated in Figure 3-8. Its ultimate purpose is the on-the-ground management of ecosystems. An example of the initial steps in the analysis process is located in Appendix B.

An important interim step in the overall process is the development of a schedule of projects, ready for the responsible line officer to give a go-ahead for NEPA analysis and subsequent implementation. Such projects would be aimed at moving the landscape to desired condition or cause it to vary within desired condition. The analysis process and results should be documented in planning records for later monitoring. The resulting prioritization and scheduling of projects are documented in a *Landscape Management Implementation Schedule* for the landscape. The term *management* here includes both active and passive "actions". The landscape analysis process helps managers address landscapes as ecosystems nested within a hierarchy of broader ecosystems. The results of this "landscape-to-projects" process may or may not lead to adjusting the Forest Plan. Most Forest Plans are flexible enough to accommodate the results of analyses, but may need to be amended to reflect more detailed information on desired condition.

For the purposes of the process illustrated below, the landscape scale from the Terrestrial Hierarchy is used. The steps in landscape level implementation are presented below in a simple linear fashion. In practical application, there are many feedback loops and internal adjustments:

- Step 1: Select a Landscape to Analyze
- Step 2: Select Key Ecosystem Elements and Their Environmental Indicators
- Step 3: Derive Recommended Management Variability for Environmental Indicators
- Step 4: Define Desired Condition
- Step 5: Determine the Existing Condition
- Step 6: Compare Desired Condition to Existing Condition
- Step 7: Identify Opportunities to Approach Desired Condition
- Step 8: List Potential Projects
- Step 9: Project Selection, Prioritization, and Scheduling in a Landscape Management Implementation Schedule

If Forest Plans contain ecosystem management-based descriptions of desired condition, one could jump immediately to determining existing condition. Since many Forest Plans do not currently meet this requirement, the entire process is described.

Furthermore, implementation of ecosystem management at the landscape level does not end with the scheduling of potential projects (Step 9). It is followed by several steps which are already familiar to us. The following steps complete the planning process:

- Step 10: NEPA Analysis and Disclosure
- Step 11: Line Officer Decision
- Step 12: Project Implementation
- Step 13: Monitoring and Feedback
- Step 14: Possible Forest Plan Adjustment

These last steps are best guided by existing reference materials (See FSM 1920, FSM 1950, FSH 1909.12, and FSH 1909.15), and are only discussed in the remainder of the chapter where there is a need to highlight the application of ecosystem management principles and concepts.

The products of these steps should be documented in the planning record. A potential pitfall is the expectation that an analysis must have perfect data before proceeding any further. Less important than developing a detailed description of a landscape is

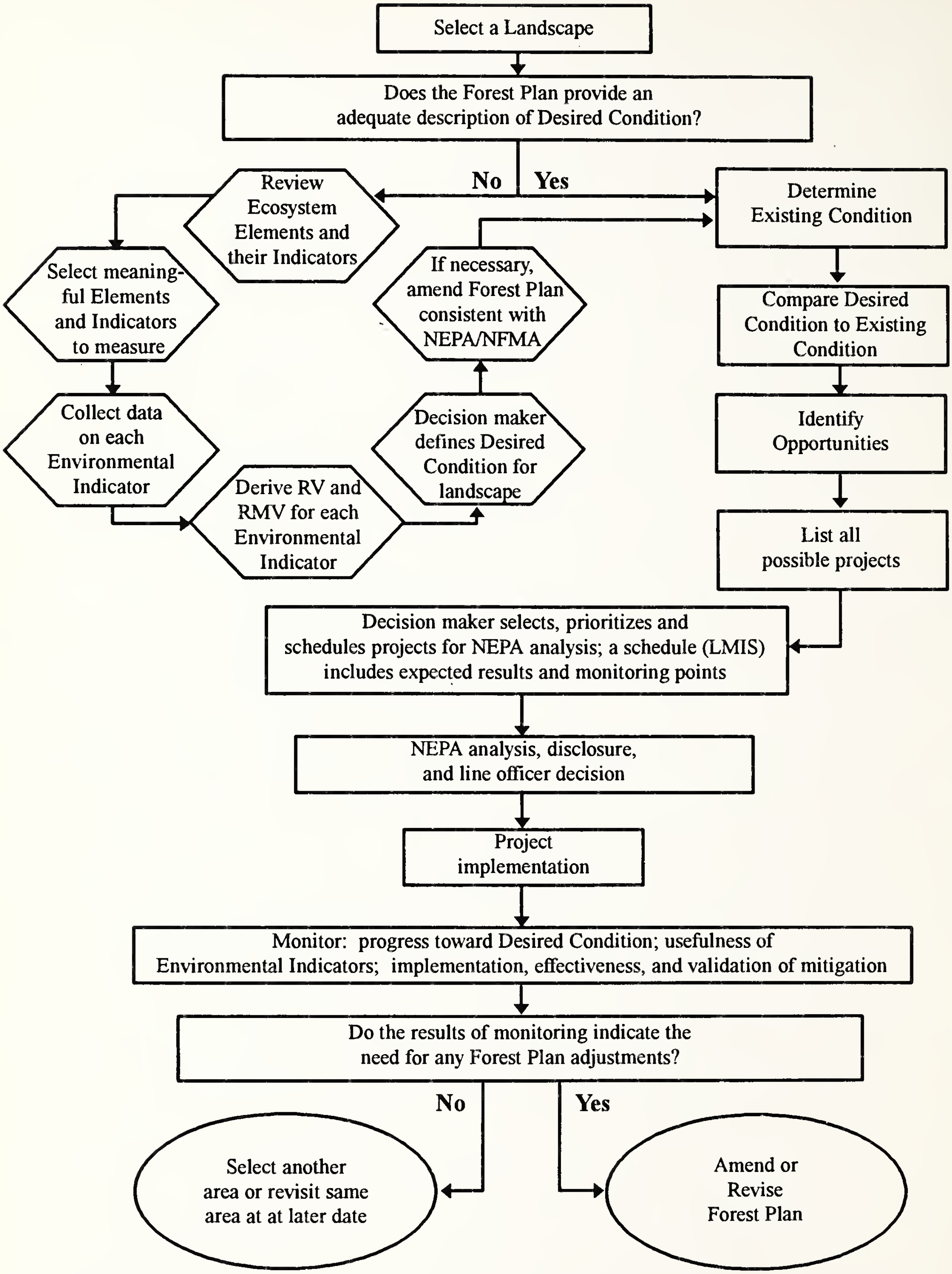

Figure 3-8. Display of the analysis and planning process at the landscape scale.

the understanding of the processes and links necessary to sustain it.

Step 1: Select a Landscape to Analyze

The size and boundaries of the landscape to be analyzed depend greatly upon the objectives of the analysis and the questions or concerns under consideration. Typically, the landscape will encompass 100s to 1,000s of acres (the area may be defined by watershed boundaries). The analysis area may include portions of one or more National Forests and other agency administered or private lands. Public involvement could be useful in this step.

The context of why analysis is being conducted at the landscape scale should be clear, before the selection process is undertaken. The selected landscape should adequately capture and reflect larger scale concerns. Watershed Analysis being conducted under the President's Forest Plan (USDA et al. 1994) is an example of placing the selection process in proper context. Criteria for selection of an area could include the availability of funding, availability of data, the perception that the area has "problems", the area's potential for outputs, or perhaps it simply has been scheduled for analysis.

The exact boundary of the area is not as important as the ecosystem components, structures, and processes included within it. For example, if the objective is to restore water quality, the landscape should outline an entire watershed or subwatershed that included sources of water degradation. The consideration of the context of the area at one scale larger and one scale smaller may prevent some Key Ecosystem Elements from being overlooked.

At this point, the Forest Plan should be consulted. If the landscape already has a desired condition description in the Forest Plan that was derived using the ecosystem management landscape analysis process outlined below, then the analysis team should extract the desired condition from the Plan and go right to the determination of existing condition, described in Step 5. The more likely scenario is that the analysis team will need to use Steps 2 through 4 to construct or refine an ecosystem management based desired condition.

Step 2: Select Key Ecosystem Elements and Their Environmental Indicators

Environmental Indicators are the representative measures for Key Ecosystem Elements. They are used and tracked throughout the entire process. For example, what species, what aspects of genetic diversity, what vegetative communities, and what land use patterns should be used as Environmental Indicators for a given landscape? This section provides background information needed to build a foundation for choosing Environmental Indicators and the types of data required.

This step begins by consulting the matrices (Appendix A) to identify Key Ecosystem Elements and their Environmental Indicators. Inherent in the selection of Indicators is the determination of the level of detail, the scope, and the quantification necessary. An analysis that tackles numerous and complex Environmental Indicators may become entangled in "analysis paralysis." The rationale for choosing the Indicators should be documented in planning records.

Analyzing Environmental Indicators is the way that the coarse-filter/fine-filter approach to conserving biological diversity is implemented in ecosystem management. The open-system/closed-system method will be used to analyze cultural/social Environmental Indicators for cultural diversity.

Without Environmental Indicators, land managers have no measures for evaluating the impact of land management actions and the sustainability of ecosystems. Several important facets must be considered when selecting Environmental Indicators. Those listed in the matrices are broad categories of ecosystem components, structures, and processes that have many levels of resolution. Selecting the Indicators can be complex because

some may serve more than one function within an ecosystem. Furthermore, when selecting Key Ecosystem Elements and associated Environmental Indicators, land managers must choose ones that:

- represent ecosystem conditions,
- reflect how management actions affect sustainability, and
- are feasible and adequate indicators of change.

General Selection Criteria

Selecting the full range of appropriate Environmental Indicators should entail convening an interdisciplinary group of resource specialists. The group should consider these questions.

- What are the building blocks of the ecosystem in the landscape? What components, structures or processes influence large areas? What are the major disturbance regimes?
- What is likely to change or be affected by human influences common to the area, and of these, what is rare, unique, or sensitive?
- Has a larger scale analysis (i.e., subregion or ecoregion) already identified Environmental Indicators that may be important to the given landscape?

Look at multiple scales and use the matrices to identify links among elements.

Coarse-Filter Considerations for Environmental Indicators

In choosing Environmental Indicators to represent biodiversity, keep in mind diversity's three levels: genetic, species, and ecosystem. *Genetic diversity* is focused on variation within species and its implications for how species persist over time. *Species diversity* is focused on the persistence of individual species as well as the diversity of species that are characteristic of a habitat condition. *Ecosystem diversity* is focused on maintaining the diversity of components, structures, and processes of ecosystems, as well as maintaining the diversity of different ecosystems within a landscape.

Genetic diversity is the basis of species viability. Connectivity and other influences on genetic exchange and uniqueness could be reflected by choosing Indicator populations, species, or genera that vary in their movement and dispersal capabilities, and in their current population structure. Some aspect of their genetic diversity should be sensitive to the changes likely to occur in the landscape. Taxonomic diversity is also a useful coarse-filter indicator of genetic diversity.

Under the Conceptual Framework's ecocentric coarse-filter/biocentric fine-filter approach, Environmental Indicators for species diversity are addressed within the fine-filter considerations section (see below). Indirectly, the Indicators suggested for genetic diversity and ecosystem diversity also address species diversity needs.

Vegetation mosaic is a Key Ecosystem Element with many indicators that reflect ecosystem diversity. Indicators include seral stage percent, patch size distribution, age structure, etc.

Process indicators are important for all levels of biodiversity. Typically, one or more components or structures will be identified, but it is important to state clearly what they represent. For example, a particular ecosystem may have a well known intermediate link or end product in an important nutrient cycling process. Important links (e.g., the symbiotic relationship between voles and hypogeous fungi) could be analyzed and tracked at the landscape scale or above, knowing that if the measures yielded disconcerting results, the populations of these species may be in trouble, and worse, an entire ecosystem process may be at risk. More simplistic approaches may be used, such as tracking the number of species in each trophic level and how it changes over time or using some other indirect measure of process such as biomass of certain biological components.

Fine-Filter Considerations for Key Elements and Environmental Indicators

Look for unique elements that:

- have special needs,
- are directly affected by human influences, and
- are already at risk.

These elements may not be "represented" by the Environmental Indicators chosen through the coarse filter process, and yet their persistence is important to maintaining biodiversity. Some potential criteria for identifying high-risk species are listed below.

- Declining population trend.
- Significant portion of range occurs within the analysis area.
- Significant portion of range occurs on National Forest System lands in Region 5.
- Highly specialized in some relevant life history characteristic.
- Rare species or community.
- Federally threatened, or endangered, or candidate species.
- Recognized as vulnerable and potentially declining (i.e., state listed, local concern, listed by other federal or state agencies).
- Taxonomically unique.
- Genetically significant subpopulation.
- Geographically unique.
- Uniquely or particularly sensitive to or affected by types of activities that are likely to occur in the area (e.g., herbicides, introductions of non-native species).

Open-System/Closed-System Considerations for Environmental Indicators

A key to sustainability of the cultural/social dimension of ecosystems is diversity. Again, this is accomplished through maintenance of a diversity of components, structures, and processes at a broad scale. A combination of open- and closed-system approaches may help identify Environmental Indicators needed to meet differing objectives. Consultation and close work with the public will help identify Environmental Indicators that capture the diversity of cultural/social elements.

Open-System Approach

An open-system approach that looks at the interconnected nature of physical, biological, and cultural/social elements, particularly at landscape or broader scales, will yield results most applicable to ecosystems analyses, by capturing the diversity in cultural elements generally inherent in broader scales. Using Environmental Indicators that reflect cultural complexities and interrelationships (e.g., group membership, demographics, income, employment rates) will be essential to understanding cultural diversity. In addition, an open-system approach that looks at Environmental Indicators through time (e.g., resource use, site patterns, demographics) will help identify trends and critical changes. Although more difficult to organize and synthesize, an open- system approach will help capture more meaningful cultural and ecosystem relationships and linkages. Comparative modeling can be utilized to tackle the difficult organization and synthesis of the multitude of cultural variables operating in ecosystems.

Closed-System Approach

Closed-system approaches focus on specific cultures or cultural elements, and can be used to highlight management for specific ecosystem cultural needs or issues. Closed-system Environmental Indicators, such as social group membership, numbers and types of resources and objects, and resource use, might be used to focus on some cultural activity practiced by a particular group, such as California Indian basket weaving, backpacking in wilderness, or enhancement of timber-dependent community opportunities. Closed-system Environmental Indicators should be analytically separable from larger cultural systems.

In the broader context, these Environmental Indicators would be analyzed to understand how a closed-system fits into the larger array of open-system Elements, and what functional role it plays. This analysis can be accomplished through comparative modeling. Once the closed-system has been identified, alternatives for the maintenance of its value and role in the open-system can be assessed.

Selecting an Array of Components, Structures, and Processes

When selecting Environmental Indicators for subsequent Reference Variability and Recommended Management Variability analyses, select a mixture of components, structures, and processes. Only through examining a given landscape in terms of these three types of Environmental Indicators, can we attempt to represent the range of conditions affecting ecosystem sustainability. If a certain component is of interest, identify Environmental Indicators that reflect that component and also the structure and process upon which it depends.

Environmental Indicators should reliably reflect ecosystem conditions or processes. Land managers should be aware that many Indicators perform several functions in the ecosystem. For example, soil is a component that is both a **structure** for mycorrhizal organisms and functions in the **process** of nutrient exchange .

Environmental Indicators representing components and structures are typically more easily defined and measured than processes, and as such, have been more commonly used as Indicators in the past. Processes are more abstract, with fewer tangible qualities to pick up and measure. In many instances the only feasible method to characterize or measure a process will be to use components or structures as proxies. When an Indicator is chosen, it is important to document what aspect of the ecosystem it is intended to represent. Multiple Environmental Indicators will reflect the environment better than the oversimplification afforded by one or a few. Moreover, if more than one process could have resulted in the pattern of interest, the Environmental Indicators must be able to distinguish the appropriate process.

Processes are the foundation upon which components and structures are built (Mills et al. 1993). Cale et al. (1989) warns that focusing only on components and structures, and not the processes that generate them, will not advance our knowledge of ecosystems. Further, Cale et al. (1989) and Duarte (1991) state that not only can multiple processes produce the same pattern, but many different patterns can result from the same process. For example, a 100-year flood occurring throughout a river basin can affect channel responses and stream habitat conditions differently in geomorphically similar and adjacent sub-basins. Conversely, multiple processes can produce similar patterns. Similar stream channel conditions could result from different disturbances, such as fire and floods, where both events produce an influx of woody debris and sediment.

When selecting Environmental Indicators, then, we need to focus on those that reflect related processes as well as the pattern. Yet, recognizing that "analysis paralysis" could easily ensue from trying to incorporate a vast array of Indicators; selected ones will always be simplified representations of a more complex and diverse system. Since budgets will limit Environmental Indicator selection, we must pick the most critical ones.

An example of selecting Environmental Indicators in relation to Ecosystem Elements and a hierarchical system is displayed in Table 3-5.

Step 3: Derive Reference Variabilities and Recommended Management Variabilities for Environmental Indicators

Optimally, the derivation of Reference Variability and Recommended Management Variability values is a step requiring on-the-ground knowledge, large amounts of data collection, and rigorous analysis

and interpretation. The tools needed to conduct this step are discussed in detail in Chapter 4. The product of this step is the description of Recommended Management Variability values for each Environmental Indicator. The objective of this analysis is to uncover those things that will restore or maintain ecosystem diversity and sustainability. Practically, consideration of data set limitations, outlier points, and best professional judgement will be used in determining Reference Variability and Recommended Management Variability for many cases into the foreseeable future.

Determining Reference Variability

Reference Variability is a baseline value. It is the range or distribution of data that characterize the way an ecosystem has operated over a given time period.

The area within which information needs to be gathered to derive Reference Variability for an Environmental Indicator will vary depending on the Indicator (Figure 3-9). Each Environmental Indicator may have a unique "analysis area" within which the information is relevant for the Indicator and the landscape being analyzed. The "analysis area" may be smaller, larger, or have the same bounds as the landscape.

Check to see if pertinent data that may apply to the landscape under analysis are already available for the chosen Environmental Indicators. Sources will include scientific literature, the research community, and Reference Variability analyses that have been conducted at a larger scale. The existing information does not necessarily need to be from the landscape under analysis — such data may be adjusted for local conditions based on best professional judgement. Whenever possible, default to existing higher level or similar information. For example, known fire return intervals specific to a vegetation series for an entire province may also be valid for the same vegetation at the landscape scale.

If no data are available or cannot be inferred, this step requires that a data set be generated for each selected Environmental Indicator. Chapter 4 provides a "toolbox" of methodologies to assist in the design and execution of Reference Variability analyses, including data collection.

Data collection should cover a specified time period to capture sufficient variability. These time periods will range from tens to thousands of years, depend-

Table 3-5. Example of Environmental Indicator selection for Key Ecosystem Elements.

Landscape:	North Fork Watershed; 200,000 acres
Concern:	ensatina salamander
Hierarchy:	Terrestrial Ecosystem Hierarchy
Key Ecosystem Element #1:	Vegetation mosaic
EI #1A: fragmentation	Unit: average patch size (in acres), by seral stage
EI #1B: total habitat area	Unit: acres by wildlife habitat relationship (WHR) type
Key Ecosystem Element #2:	Animal Species (ensatina salamander)
EI #2A: demographics	Unit: number of animals
EI #2B: distribution	Unit: spatial/temporal data on habitat areas

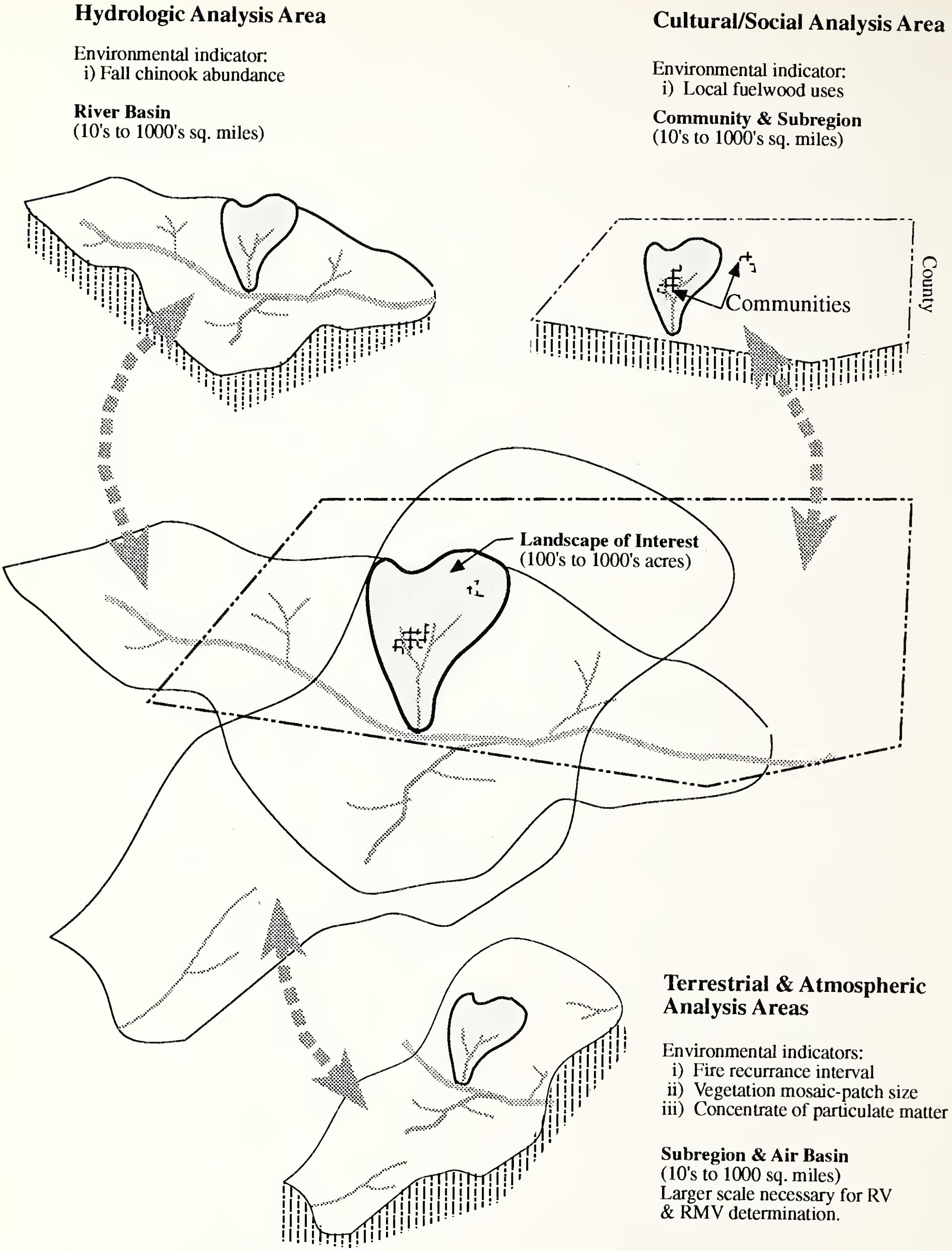

Figure 3-9. Potential range of analysis scales necessary for Reference Variability determination for a given landscape.

ing on each Environmental Indicator and data availability. For some Environmental Indicators, contemporary reference data from representative areas (not necessarily located in the same landscape) may be used as a proxy for historical data (i.e., swapping space for time). The types of data collected are dependent on the characteristics of the Environmental Indicators selected and the context of the ecosystem analysis.

Once a sufficient amount of data are gathered, a statistical analysis is in order to fit the values to a curve or otherwise plot their distribution. Such analysis can also give insight as to the data's reliability. Qualitative information should be evaluated using best professional judgement supported by scientific findings. For both qualitative and quantitative data, overall interpretation is needed to determine if any findings, trends, or conclusions can be made.

Determining Recommended Management Variability

Reference Variability includes the outer bounds of what nature and people have historically done. Accordingly, Recommended Management Variability is derived from Reference Variability by eliminating the part of the data set representing extreme events that management and — ultimately — the public would not want to replicate. Examples would include 500 year floods, communities turning into ghost towns, and large stand-replacing fires.

Recommended Management Variability is not a decision. It is a recommendation made by resource professionals for management to consider in their subsequent adoption of a desired condition.

Step 4: Define Desired Condition

Desired condition is determined by the weighing and balancing of physical, biological, and cultural/social system needs and objectives. Decision makers will want to select a desired condition for the landscape that is within Recommended Management Variabilities for as many Environmental Indicators as possible. Being within the Recommended Management Variability for one Environmental Indicator may result in being outside Recommended Management Variabilities for other Indicators. Therefore, conflicting or mutually exclusive desires may need to be evaluated and trade-offs made. The values representing the cultural/social dimension of desired condition are often translated into land and resource conditions.

A proposed landscape-level desired condition should be tested by evaluating it at one scale larger and one scale smaller. At the higher scale the goal is continuity and consistency; at the smaller scale, a disaggregated desired condition should still be feasible.

The adoption of desired condition for a landscape is a management prerogative that forges a "contract" with our public. As such, it should be based on a collaborative decision building process. If the desired condition selected is outside the inherent flexibility of the current Forest Plan, or if the Plan's description is inadequate, amend the Plan using appropriate NFMA/NEPA procedures. Even the interpretation or refinement of desired condition within the flexibility of a current Forest Plan should include some level of public involvement.

Step 5: Determine the Existing Condition

Now that the desired condition for the landscape under consideration is known, the existing condition needs to be described in comparable terms. The description should be in the same quantifiable Environmental Indicator parameters used in the desired condition. Defining the existing condition of the landscape may involve the application of integrated inventory techniques, especially for the physical and biological dimensions of the landscape. Describing the existing condition of the cultural/social dimension of the landscape will usually require a look at information at a broader

scale (subregion or ecoregion). Flows of energy and matter across the boundaries of the landscape should be captured in its description (e.g., air pollution). Again, a potential pitfall is the expectation that perfect data are required before proceeding any further.

Step 6: Compare Desired Condition to Existing Condition

To conduct this comparison, the elements of desired condition and existing condition must use common units. For example, comparing a desired condition component expressed as average forest patch size to the same area's existing condition described as species composition is analogous to comparing "apples and oranges". Under the Conceptual Framework, desired condition will be expressed as a distribution of conditions, while the existing conditions, a snapshot of one point in time, may be a single condition. Figure 3-10 illustrates this concept.

On the other hand, existing condition could be a distribution of values found from site to site across a landscape (e.g., patch size varies from X to Y with average Z and mode M).

Step 7: Identify Opportunities

When desired and existing conditions are compared, our *opportunities* come to light. Opportunities are not projects; they simply describe what needs to be accomplished to achieve or maintain desired condition. For example, the need to stabilize the riparian vegetation along a stream is an **opportunity**; possible **projects** arising from that might include the planting of willows or the fencing of the area to restrict livestock access.

When the opportunities have been described, a clear picture develops, showing what needs to be accomplished in the landscape in both time and space. This image reveals options for projects.

Step 8: List Potential Projects

At this stage, we openly and freely identify possible projects (or management practices) to move the landscape toward desired condition. Accepting each idea without criticism or evaluation is appropriate in order to encourage innovation. Collaborative planning may be effective here in the identification of possible projects, as the public or other agencies may be aware of potential solutions not obvious to the Forest Service.

The product of this step is a "laundry list" containing all conceivable projects that would achieve the desired condition. The sequence and timing of project implementation can be critical to efficiently move toward desired condition. For example, reestablishing the meanders for a stream would need to occur before planting willows and alders to reduce temperature. So, a list of "project packages", each being a sequential listing of individual actions or practices, would be developed.

Reaching or maintaining desired condition will depend on ecological and human circumstance. Funding levels for various types of projects are the most influential human constraint. Ecosystem conditions are likely to be just as limiting. Even reaching desired condition for a particular Environmental Indicator may depend upon the presence or condition of some other Indicator.

Documentation in the planning record should discuss and explain the duration of ecosystem processes required to reach desired condition. If achieving the desired condition requires a long time, several projects may be required. Because projects may need to be conducted in sequence, the project description should document the processes affecting Environmental Indicators, the temporal dimensions over which they operate, and the estimates of the minimum and maximum time required to reach desired condition.

Projects and their accompanying rationale should be presented in an unbiased manner for subsequent review by Forest Service decision makers. In addition, it will be helpful to note whether each

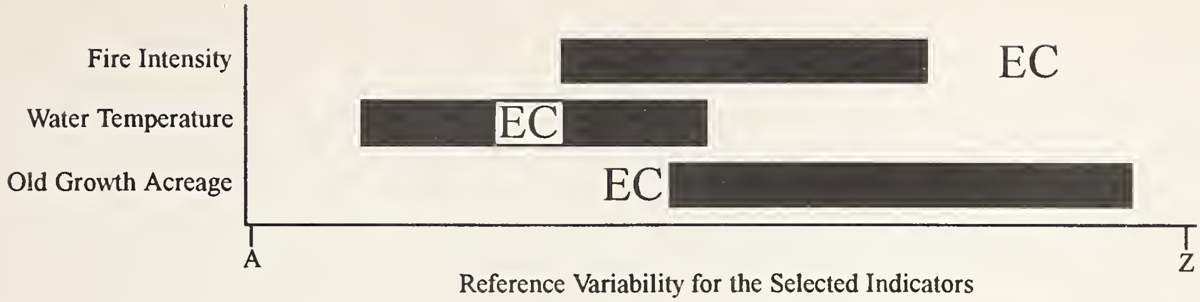

Figure 3-10. Comparison of desired condition to existing condition. This illustration shows the range of desired condition (bars) and point of existing condition (EC) for three Environmental Indicators. The axis represents a composite Reference Variability distributed in values from A to Z.

possible project is consistent with the Forest Plan and NFMA. Otherwise, they can only be implemented after being modified for consistency, or if the Plan is amended. Projects inconsistent with NFMA requirements (e.g., ability to reforest within five years) cannot be implemented and thus should not be considered further.

Step 9: Project Selection, Prioritization, and Scheduling in a Landscape Management Implementation Schedule

This step requires substantial decision maker involvement and discretion in determining which projects, or project sequences, will actually be implemented. Line officers review the entire "laundry list" of possible projects and select one or more that would best maintain or achieve desired conditions. Some combinations of projects will produce synergistic effects on maintaining or restoring ecosystems. Prudence would dictate that line officers would seek staff advice from the team that analyzed the landscape and derived the Reference Variability and Recommended Management Variability values. Project selection criteria should consider the following questions.

- How well and quickly does each project maintain or move the landscape toward achieving desired condition?
- What are the risks associated with doing nothing (if doing nothing wasn't identified as a possible project)?
- How well does each project protect rare, unusual, or critical Elements?
- What are the potential cumulative effects of the project on sustainability and diversity at the landscape scale?
- How efficient is each project? Is the cost of implementation commensurate with the expected benefits? Is sufficient funding likely to be available?
- Does the project provide important public goods, services or values?

The prioritizing and scheduling of projects should be documented in a *Landscape Management Implementation Schedule*. Scheduling will facilitate the allocation of limited funds and workforce, and possibly allow a Forest Service unit to line up partnerships well ahead of actual implementation. Also, as discussed above, scheduling can be utilized to outline a sequence of work, as the order in which the landscape is manipulated may better ensure ecosystem sustainability. Projects in the schedule will then be carried over into the NEPA process as proposed actions.

Conceptually, the Landscape Management Implementation Schedule can be viewed as a "landscape prescription", analogous to the silvicultural prescription for an individual land unit.
The schedule should cover the management period

from the present until desired condition is expected to be reached, with the greatest detail on what will occur over the coming 10-15 years. Each project may be accompanied by specific objectives and time frames for accomplishment. Long periods of time will be typical for landscapes which are further away from the desired condition, since many ecosystem processes may not be hastened.

The Landscape Management Implementation Schedule should also contain projections of expected results of projects and associated monitoring actions. Monitoring should address the effectiveness and validity of Environmental Indicators, and progress toward desired condition. Since selected Environmental Indicators are assumed to be meaningful representations of ecosystem function, they need periodic evaluation and refinement. Monitoring is discussed further later in this chapter. Table 3-6 illustrates the possible contents of a Landscape Management Implementation Schedule.

Step 10: NEPA Analysis and Disclosure

This step will only be described in brief form, because much of it involves familiar NEPA material. Implementation of ecosystem management objectives requires up-front selection of appropriate projects to be carried forward; these require NEPA analysis and disclosure. NEPA analysis is **not** the place to begin applying ecosystem management principles. A project with objectives incompatible with ecosystem management principles cannot easily be converted into an action consistent with such goals.

Proposed Action/Purpose and Need

The purpose of most projects will be to maintain or move a landscape toward the desired condition. All proposed projects should have been previously identified in the Landscape Management Implementation Schedule. Project objectives should no longer focus on the traditional accomplishment of administrative targets — allowable sale quantity (ASQ's), animal use months (AUM's), etc. — but on land conditions. Project-specific objectives may be formulated for tracking measurable accomplishments.

Scoping

Ecosystem management should lead to stronger and broader public involvement efforts that include conservation partnerships, traditional cultural groups, and collaboration.

Issue Identification

Identify and clarify cause and effect relationships of the issues. Most issues will be measured through the use of Environmental Indicators selected earlier. Additional Indicators can and should be added at this stage of the process, based on unique attributes of the project or the project area.

Effects Analysis

Disclose the effects of the project alternatives on the physical, biological, and cultural/social dimensions at relevant ecosystem scales. Use representative Environmental Indicators as a basis for displaying the consequences of the alternatives considered.

The effects analysis will disclose how each alternative contributes to the achievement and maintenance of desired condition. The Environmental Indicators should reflect aspects of the ecosystems affected by the project directly, indirectly, or cumulatively.

It is at this step that addressing and disclosing cumulative effects and benefits at the landscape scale is critical. Cumulative effects should be addressed in terms of past, present and future actions (the Landscape Management Implementation Schedule is a good source of expected future actions). Any analyses that show that the project will maintain or move the landscape outside Recommended Management Variabilities for one or more Environmental Indicators should be disclosed. Table 3-7 shows how alternatives may be compared.

Table 3-6. Hypothetical project schedule in a Landscape Management Implementation Schedule. To assess the spatial component of desired condition, the schedule should address every stand in the landscape, thus, this table is a simplification.

Project or Action	Objective	Start NEPA	Implementation Dates
Thin trees < 10" in Stands 5, 38, 79	Reduce fuels, eliminate true fir	10/95	Summer 1996
Burn willows in stand 14	Produce basket making material for local Tribe	10/95	Spring 1996, Spring 2001
Develop a spur Cross Country ski trail	Expand Cross Country ski opportunities	1/96	Summer 1997
Monitor fire regime landscape-wide	Validate fire return interval Environmental Indicators	n/a	1996
Underburn stands 38, 79	Reduce fuels, nutrient cycling	1/96	Fall 1999
Obliterate and revegetate roads #213, 215	Restore watershed integrity	3/96	Summer 1997
Let stands 5, 38, 79 grow	Develop old growth characteristics	n/a	1996-2089
Group selection harvest in stands 2, 7, 40	Regenerate desired intolerant trees	4/96	Summer 2000
Monitor characteristics of stands 5, 38, 79	Determine success of treatments and progress toward old growth	n/a	2009, 2029, 2049, 2069

Note that the comparison includes contrasting the alternatives to both desired condition and existing condition, and that a temporal factor is included.

NFMA Findings

Document NFMA findings on consistency with the plan, suitability for timber production, clearcutting and even-aged management, and vegetation manipulation as described in FSH 1909.12, 5.31a.

Significance

Whether or not an action produces a sustainable ecosystem may be a possible indicator of significance for environmental assessments.

Step 11: Line Officer Decision

As decision makers choose to implement projects on-the-ground, their selection criteria will be influenced by ecosystem management objectives (i.e., achieving or maintaining Recommended Management Variability). The rationale for being outside Recommended Management Variabilities for one or more Environmental Indicators should be disclosed in the decision document.

Step 12: Project Implementation

Project managers may wish to consider the use of conservation partnerships to facilitate project

Table 3-7. Hypothetical comparison of environmental effects. Note that the comparison includes contrasting the alternatives to both desired condition and existing condition, and that a temporal factor is included.

Ecological Indicator	Existing Condition	Desired Condition	Alternative A (No Action)	Alternative B	Alternative C
Fire Severity (% low)	25%	60 - 90%	25% in 1 yr 35% in 5 yrs	25% in 1 yr 65% in 5 yrs	45% in 1 yr 70% in 5 yrs
Maximum Water Temperature	65°F	50 - 55°F	65°F in 5 yrs 60°F in 5 yrs	60°F in 10 yrs 50°F in 10 yrs	60°F in 5 yrs 55°F in 10 yrs
Old Growth Acreage	15%	20 - 30%	16% in 50 yrs 17% in 90 yrs	20 % in 50 yrs 25% in 90 yrs	20% in 50 yrs 30% in 90 yrs
Bear grass Acreage (for baskets)	0 acres	5 - 10 acres	0 ac. in 5 yrs 0 ac. in 10 yrs	0 ac. in 5 yrs 5 ac. in 10 yrs	3 ac. in 5 yrs 5 ac. in 10 yrs
Miles of Cross Country Ski Trails	22	40	22 in 2 yrs 22 in 5 yrs	30 in 2 yrs 35 in 5 yrs	35 in 2 yrs 40 in 5 yrs

implementation. Adjacent jurisdictions, landowners, and others have a long-term interest in what is a common enterprise with ramifications across the landscape.

Step 13: Monitoring and Feedback

Monitoring under ecosystem management will emphasize the effectiveness and validity of basic assumptions, such as whether:

- projects are being implemented as planned;
- projects are effective in achieving desired condition;
- appropriate data values for Environmental Indicators were used in Reference Variability and Recommended Management Variability; and
- desired condition is realistically achievable.

Monitoring will simultaneously address both project (land unit) and landscape scales. Monitoring results can be used to trigger adaptive management adjustments. Projects could be framed as scientifically driven experiments that test ecosystem management predictions and assumptions. Management practices can then be adjusted in increments to further fine-tune the maintenance or movement of a landscape toward desired condition.

The annual Forest Plan Monitoring and Evaluation reports would be a likely place to highlight the findings of monitoring actions. Storing the monitoring data in a GIS system and planning file will make the information accessible and useful.

Monitoring Environmental Indicators

Monitoring plays an important role in validating basic assumptions behind Environmental Indicator selection, estimating Reference Variability, and

measuring our management effectiveness in meeting objectives. To evaluate and fine tune our ecosystem management methods and theories, we employ three distinct levels of monitoring that interact with each other: implementation, effectiveness, and validation. These three levels of monitoring together serve to observe and record results of management.

Implementation monitoring simply asks the question: were project actions and mitigations carried out as planned? As such, it has little direct effect on tracking Reference Variability and Recommended Management Variability.

Effectiveness monitoring focuses on the successful identification, selection, analysis, design, and performance of projects. All activities and projects should have been designed to move the landscape toward the desired condition. If the project produces expected results, then it should be considered effective. Short term objectives should have been designed to be measurable so that project success can be evaluated. Therefore, the Environmental Indicators can be used to track how well the projects are producing expected results. Differences between the actual and desired values would indicate a need to refine management practices and tools, as well as the possible need for reassessing baseline data quality and validity of assumptions.

Validation monitoring examines the validity of baseline data and ecosystem management strategies that are assumed to be useful in moving toward desired condition. It questions whether assumptions underlying the selection of an Environmental Indicator are correct, and if subsequent estimates of Reference Variability and Recommended Management Variability are accurate. Validation monitoring examines the assumed cause and effect relationships, and seeks opportunities to utilize new information in refining estimates of Reference Variability and Recommended Management Variability. As new information relative to the validity of assumptions underlying ecosystem treatments and practices develop, our vision and basic knowledge of how ecosystems function becomes more accurate. For example, as new information relating to species life history and the accuracy of habitat suitability develops, estimates of Reference Variability for population parameters and habitat quality indices will become more accurate.

Step 14: Possible Forest Plan Adjustment

Evaluating monitoring results at the landscape scale also provides a feedback mechanism to higher level descriptions of desired condition, such as the Forest Plan level. Forest Plan direction can be supplemented and refined to better reflect Reference Variability and Recommended Management Variability based desired conditions. Forest Plans, as dynamic resource coordination documents, will require continual and scheduled reassessment to validate the accuracy of their forest-wide and management area specific desired conditions. Major disturbance events that affect site potential could trigger adjustments to desired condition, since it must be based on the capabilities of the land. Social and economic changes are also likely to change Forest Plan goals and objectives.

Ecoregion/Subregion Scale Analysis

The main thrust of this chapter, landscape scale implementation of ecosystem management concepts, was described above. The integration of ecosystem management principles at larger scales is also important, but will occur less often, and typically at the Regional or province administrative levels. Thus, only a brief summary of this level of analysis follows.

To fully implement the concepts of ecosystem management, areas larger than individual National Forests must be analyzed. For example, the management of California spotted owl habitat has highlighted the need to take an ecosystem approach for major portions of an ecoregion. For such wide-ranging species, viability cannot be accomplished

by only evaluating habitat needs at lower levels of the hierarchy. Viability can only be assured by addressing species' needs over their entire range. However, the spotted owl represents a biocentric approach to conservation that should not be the sole basis for subregion or ecoregion analyses. Ideally, analyses of Ecosystem Elements will be conducted for subregions and ecoregions in Region 5 motivated by the need to supply information about ecosystems as a whole to facilitate planning at all scales.

Analysis areas will often transect many administrative boundaries. In some cases, even Regional boundaries will be too small or will bisect ecosystem units. For instance, large-scale analyses conducted for the eastern Sierra Nevada will include portions of the Toiyabe National Forest in Region 4. Furthermore, some data needs at larger scales cannot be accommodated at the landscape level. Analyses at higher scales will need to be identified as a priority at a Regional level, and tasks will be assigned to individuals throughout the Region. The recent adoption of a corporate data policy is moving the Region in the right direction.

The purpose of the analysis process at the ecoregion/subregion scale is the generation of desired condition descriptions at this large scale. Such desired conditions provide umbrella direction to be used at the landscape scale, thus ensuring consistency across scales. The Regional Guide is an example of higher level analysis and direction at the ecoregion scale. A benefit of this type of analysis would be consistency and continuity of common goals and objectives for an ecologically distinct area that encompasses more than one administrative unit (e.g., Klamath Province). Furthermore, through the use of partnerships and interagency cooperation, ecoregion/subregion analyses could address entire ecosystems that include substantial amounts of land not administered by the Forest Service.

One challenge of undertaking larger scale analyses is that they go beyond traditional Forest level planning. As ecosystem management concepts are contemplated, it becomes obvious that existing Forest Plans did not fully consider sufficiently large areas. Thus, the emerging need for ecoregion and subregion scale analyses becomes quite evident. To effectively implement ecosystem management objectives, the Forest Plans of the future will most likely encompass multiple National Forests. Additionally, these plans will need to assess land management practices on multiple ownerships, both intermingled and extending beyond National Forest boundaries, as ecologically appropriate. Cooperative work with other ownerships may be crucial to the maintenance or restoration of some ecosystems. The planning process of the future may well be labeled "ecoregional multi-agency ecosystem based planning."

There is no single approach to conducting ecoregion and subregion scale planning, thus the following outlines the major steps of one possible option. These steps are very similar to the landscape scale process described above. However, while analysis and planning at the ecoregion and subregion scales only develop general descriptions of desired condition, the process at the landscape scale is taken further and used to generate possible projects. The four major steps of this process include:

- Step 1: Select Analysis Area
- Step 2: Select Key Ecosystem Elements and Associated Environmental Indicators
- Step 3: Determine Reference Variabilities and Recommended Management Variabilities for Environmental Indicators
- Step 4: Define Desired Condition

Desired condition as a product of the last step of this larger scale analysis, will need to be captured, documented, and made readily available for subsequent planning efforts. These new descriptions of desired conditions should be incorporated into the Regional Guide or Forest Plans, through the amendment or revision process. Since desired condition is a "contract" with our public, the adoption of new

desired conditions includes appropriate public participation and NEPA compliance.

Once completed, the desired conditions adopted at this larger scale should remain relatively constant and unchanged for extended periods of time. Thus, every time a landscape within the ecoregion/ subregion is analyzed, there is no need to continually reinvent the larger scale desired condition.

Public Participation Under Ecosystem Management

Public participation is a critical element in implementing ecosystem management. More people than ever want a say in the natural resource decisions that affect their lives and are demanding to be included in the decision making process. Now is the time to increase our efforts to include and listen to all members of the public. This section outlines many considerations of and approaches to public participation that the Region will use as operational axioms for ecosystem management.

When is public participation needed in the overall ecosystem management analysis and planning process? We know that public participation is required during NEPA compliance for amending or revising the Regional Guide and Forest Plans, and before a site-specific project can be implemented on-the-ground. Public participation is also desirable in the analysis of ecosystems for the purpose of developing Reference Variability, Recommended Management Variability, desired condition and the Landscape Management Implementation Schedule. What is not as clear is how much participation is needed, and by whom.

Typically, "focused" public participation will be used when conducting informal analyses in which NEPA is not required (NFMA analysis). For example, the scientific and academic communities would be good sources of information to validate data and methodologies for determining Reference Variability and Recommended Management Variability values. However, opening such a process to the general public may be highly effective, as the comments of long-time residents can provide invaluable information and support. It is very important that resource specialists inform the participating public that this analysis process does not produce decisions as required by NEPA, thus they are not subject to appeal. This distinction must be clear to the public at the onset.

Less-focused and more extensive public participation is required by law and regulation when conducting planning for NEPA analysis and disclosure. The end-product is clearly a decision made by the responsible official. Public participation is essential to ensure that the final decision is both informed and legal. Regulations require that the public be notified by:

- publishing planning actions in quarterly schedules;
- circulating some documents (i.e., draft Environmental Impact Statements and Environmental Assessments); and
- publishing opportunities for comment or appeal in selected newspapers of general circulation.

Every public participation process needs to be tailored to the unique circumstances of the analysis area and the people involved. Consequently, general guidance regarding public participation rather than a set of detailed instructions is provided. Consult public affairs staff and public participation manuals for further information.

Recommendations for Effective Public Participation

There is no "One Size Fits All" public participation process. Good judgment and imagination are necessary to select the right technique for each situation. These recommendations are organized to follow a sequential approach to planning a public participation strategy.

Start Early

Start public participation early and make it on-going. Involving the public should be one of the first considerations in any analysis or planning activity. Ask people how they would like to be involved. Building trust and long-term relationships takes time.

Commit the Necessary Resources, Time, Funding, and Staff

Collaborative processes require staff time and agency support to succeed. Make sure the human and financial resources are available; also ensure that enough time is allocated before a commitment to a collaborative process is made. Effective public participation is the responsibility of the line officer in charge of the process.

Consult Public Affairs Staff

Public affairs staffs should be consulted before any public participation plans are made. Public affairs specialists should be asked to assist with the development of public participation strategies for impending actions. Planning and coordinating public participation is their expertise.

Articulate Processes, Constraints, and Time Lines

Agency managers need to better define analysis and planning processes and be clear to both employees and the public about how input will be used. If decisions are being made, participants need to be informed and advised about how they can participate at the appropriate level. Think the process through, describe it clearly, and explain the constraints.

Provide a Fair and Open Process

A fair process treats everyone the same, no matter where they live or what their point of view. All concerns and values are heard and acknowledged. An open process means that all relevant data will be made available. Help people interpret the data if it is difficult to understand. Deal with the public honestly, admit when you make mistakes, and make it easier for people to interact with the agency.

Consult and Collaborate Where Treaty Rights and Trust Responsibilities May Be Affected

Consultation with tribal governments should be consistent with Federal trust responsibilities and the government-to-government relationship between the U.S. and Federally recognized tribes. This is in addition to other specific Federal requirements pertaining to Tribal, Native American community, spiritual, and traditional/cultural use.

Determine Whether the Federal Advisory Committee Act Applies

Sometimes it may be appropriate to form a formal advisory committee under the legal requirements of the Federal Advisory Committee Act (FACA). However, most public participation does not fall under this act. Plan the public participation process carefully and when in doubt, consult with the Office of General Council. When the planning actions are leading to a NEPA decision, collaborative processes cannot be used to exclude anyone who would otherwise be involved.

Communicate

Keep the public and employees informed. Don't surprise people. Don't let the process disappear until a determination or decision is announced six months or a year later. To the extent possible, avoid jargon by using clear, non-technical language.

Conduct Community Social Assessments

Take the pulse of the community. This may involve both the simple act of building relationships and a

more technical scientific analysis of community groups. A social assessment will assist agencies in understanding community issues, desires, and identifying both informal and formal communication channels.

Make Efficient Use of the Public's Time

Collaborative processes take time and energy. Limitations on the amount of time available to bring analysis or planning to a conclusion, and the amount of time people have to devote to participation in a collaborative process, are real and must be acknowledged.

Be a Catalyst for Grass-Roots Efforts

Find ways to be just one of the players in grass-roots efforts that include but transcend federal jurisdictional boundaries. Allow people to build and take ownership in a process that meets their needs.

Involve People On-the-Ground

Invite people to assist with inventory, implementation, and monitoring activities in a hands-on way. Get them actively involved in resource management by taking them out to the field to view and discuss the condition of ecosystems.

Create Partnerships

Join with other government entities, land owners, interest groups, communities, and businesses to work toward a common goal. Partnerships build on the resources of the participants for mutual benefit. Good communication is essential to successful partnerships.

Provide Education Forums/Training

Sponsor educational forums on ecosystem management concepts and principles or collaboration training; invite/include the public.

Use Multiple Participation Techniques

Meetings are not the only way to conduct public participation. Let the goals of actions determine techniques, not vice versa. Consider informal interviews, public workshops, field trips, on-site demonstrations, group discussion sessions, or open houses.

Create Incentives for Collaboration

Recognize and reward employee efforts to build collaborative relationships with the public. Give citizens incentives to engage in collaborative rather than adversarial behavior by providing opportunities for constructive development of ideas and solutions to problems. Effective collaboration efforts attract attention, funding, and agency support.

Questions to Ask When Planning for Public Participation

Any public participation effort requires analysis and planning to develop a strategy that meets the needs of a specific situation. To be effective, public participation efforts need to be tailored to the people affected by the action at hand. Planning will help ensure that the process benefits everyone involved. Effective public participation is a creative process; more of an art than a science. It relies on building personal relationships with people who have an interest or concern about public lands. By its very nature, public participation will be different every time, depending on the people involved and the issues at hand.

Ask these questions in the process of developing a public participation strategy:

Who is Interested?

- Who might care about the outcome of the analysis or planning action?

- What different perspectives and concerns do they have?
- How can their concerns be better known and understood?

What's Realistic?

- What is the purpose for public participation?
- How will public input be used?
- How long will this process take?
- What resources of time, funding, and staffing will be needed?

What is the Action?

- Is the analysis and/or planning action going to lead to a decision?
- What are the constraints on the process?
- What are the limits of the Forest Service's authority?
- What is the role of public involvement in this process?

What are the Major Public Participation Challenges and Opportunities?

- Have all the possible alternatives and opportunities to involve the public been considered?
- What are the potential obstacles to achieving stated goals?
- How can these obstacles be overcome?

What is the Public Participation Strategy?

- What process meets both Forest Service and public needs?
- Who will coordinate the effort?
- When, how, and by what methods will the public be informed throughout this process?
- How can interested, non-local people be involved?
- What can be done to ensure the public's time is well invested?
- What information is sought from the public; and how will they receive feedback on how their input was used?

How Will The Strategy be Evaluated and Revised, if Necessary?

- Is the process meeting stated goals?
- How could the effectiveness of public involvement efforts be improved?
- How can problem situations be handled to make things better?
- What has been learned from mistakes?

Chapter 4

Reference Variability: Methods of Derivation and Application

Table of Contents

Chapter 4
Reference Variability: Methods of Derivation and Application

We must accept nature for what we are able to observe it to be, not for what we might wish it to be.

Daniel Botkin

This chapter provides some guidance about tools and techniques for deriving Reference Variability values. It assumes that the analysis area, Key Ecosystem Elements, and Environmental Indicators have already been selected (as described in Chapter 3, steps 1 and 2 of the analysis and planning process). The discussion outlines:

- setting the historical context,
- the nature of variation,
- data sources and analysis techniques, and
- data collection.

Reconstructing the past can be challenging — for Reference Variability one needs to gather enough information to determine how Environmental Indicators have varied over time. In many cases, the desired quality of quantitative data for deriving such values will not be readily available. It may take considerable time and coordination between and within Forests, as well as with other agencies, to develop strategies, protocols, inventories, and procedures for obtaining the full array of data.

However, a surprising number of data sources and analysis techniques are available to help derive Reference Variability. Often, data needed exist in some form on individual Forests, at Universities, and other agencies. Since collecting new information using state of the art technology can be quite costly, managers should try to locate all applicable, existing data first. In the short term, land managers may have to rely on existing information and their best professional judgement to develop Reference Variability until more quantitative data become available.

Deriving Reference Variability values requires the investigation of historical and current conditions. The temporal dimension, ranging from annual (yearly) to millennial (thousands of years), is central to defining the variability that existed throughout a particular time period. The following outlines the major phases of California's history and provides a brief historical context for the discussion of Reference Variability.

Setting the Historical Context

200,000 - 10,000 years ago

A series of major continental glaciations occurred over the past two million years. Much of the Californian landscape was shaped by the latest full glacial period which culminated 20,000 years ago (Pielou 1991). Most of the mountain ranges in California were affected to some degree by glaciation during the Pleistocene epoch. With the capturing of so much water in ice, sea levels were approximately 300 feet lower at the height of the glacial advances. Vast shallow interior lakes covered

much of what is now scrub desert in southeastern California and the southern San Joaquin Valley (Chartkoff and Chartkoff 1984:32, 52).

At times of glacial maximum, a vast land bridge extended across the Bering Straits, connecting North America with Asia. Numerous species migrated across this bridge. Humans migrated across the Bering Strait from Asia to North America during the last glacial advance, and spread south throughout the Americas. These Paleoindians followed a lifestyle centered around the hunting of large Pleistocene fauna. By 10,000 years ago, they were thinly scattered across the various portions of California where preferred big game, such as mammoth and bison, flourished (Chartkoff and Chartkoff 1984:32, 52).

Around 10,000 years ago, the biosphere underwent rapid and significant changes, notably a world wide warming accompanied by increased atmospheric carbon dioxide, increased ocean temperatures, vast vegetation shifts, and mass extinctions of North American mammals. More than 35 genera disappeared in North America during this period (Martin and White 1967; Pielou 1991). Great size and strength were an advantage to species during the Pleistocene, but those species surviving into the new environment of the Holocene (recent) epoch were the smaller, quicker animals. It has been postulated that the migration of humans into the Americas during the last glacial advance and their subsequent intense hunting of megafauna hastened the Pleistocene extinctions during this period of vast environmental change (Martin 1963:70; Martin and White 1967; Chartkoff & Chartkoff 1984: 65-69).

Warmer climates triggered the many environmental changes that led to California's modern biological assemblages. Plant and animal species that were adapted to colder climates retreated to higher elevations and northerly latitudes. Interior basin lakes dried up. Douglas-fir replaced lodgepole pine on the coast. Forest fires increased in frequency, and salmon species invaded the once glaciated rivers of the west coast of North America (Pielou 1991).

10,000-2,000 years ago

During the past 10,000 years, the North American climate completed its postglacial warming and started on a long, gradual cooling trend, most likely leading to the next glacial period. Essentially modern plant and animal assemblages were formed and existed during this time. Climatic conditions were relatively stable. Plant and animal species and human populations adapted to and affected their new environment.

With the extinction of the Pleistocene megafauna, humans diversified their economy by following seasonal rounds to take advantage of the many different species of small animals and plants available. Diversification allowed them to expand into new territories; as a result, human populations steadily increased. By the end of this period, human populations reached large numbers. They had significant effects on California's environments, particularly along drainages at lower elevation (Chartkoff and Chartkoff 1984:74-97; Woolfenden 1994).

2,000-200 years ago

Approximately 2,000 years ago, aboriginal populations reached their maximum levels in California, totaling over 300,000 prior to Spanish settlement (Cook 1978; Woolfenden 1994). Coastal areas, valley and foothill drainages, and other preferred locations were intensively exploited and manipulated. California native peoples employed a variety of resource management techniques to foster production and quality of certain plants and animals — such as specific grasses, sedges, ferns, or shrubs used for basketry, oaks for acorn crops, and salmon and seafoods — in selected locations and at predictable times. They burned, pruned, cultivated, selectively harvested, and otherwise managed the landscape to create and maintain preferred habitats (Chartkoff and Chartkoff 1984; Blackburn and Anderson 1993; Woolfenden 1994).

The past 200 years

Over the past 200 years, human populations in California have greatly increased, affecting plant and animal species composition and distribution, water resources, and many physical processes. Initial Euroamerican settlements in the late 1700s and early 1800s — Spanish missions, Russian and Anglo-American fur trapping, and early Euroamerican settlements — were thinly scattered over coastal and some interior areas. Euroamerican populations slowly increased with the change from Spanish to Mexican government. In 1848, the transfer of California from a Mexican province to an American territory, and then the discovery of gold were catalysts for tremendous change. The gold rush of 1849 ushered in rapid population growth and extensive resource exploitation. Mining, logging, agriculture, and water diversion supported development and industrialization, changing the character of major portions of California's ecosystems (Castillo 1978; Schuyler 1978; Lux 1994).

Population densities precipitated significant environmental changes. Many species of animals and plant declined in numbers or became extirpated in California. Large predatory animals, in particular, declined in diversity and number. Indigenous fish fauna changed dramatically. Thirty-seven percent of the fish species now present in aquatic ecosystems in California were introduced within the last century. Native fish populations have disappeared in low-elevation terrain. These events stem mostly from habitat alteration, exotic native species introductions, and fishing.

Aquatic ecosystems in particular experienced many changes. The vast lakes and tule marches that once occupied the Central Valley are now agriculture complexes. The Sacramento-San Joaquin Delta, once an enormous tule marsh, now consists of dredged channels with high levees. Other major activities altering aquatic ecosystems include hydraulic mining, flood control, dams and reservoirs, pollution, logging, and fishing.

Fire exclusion in forested and grassland habitats also had dramatic effects. It created excessive accumulations of fuels, leading to less frequent but more severe fires and a conversion from fire resistant to fire intolerant plant species.

Today, over 30 million people live in California. Although climatic conditions are not changing quickly, the increasing density of people continues to create rapid environmental change with uncertain consequences.

The Nature of Variation

Reference Variability is intended to reflect ecologically and culturally significant variations over space and time that, in total, characterize the conditions to which ecosystems are adapted. Understanding general ecosystem patterns is important before attempting to gather information to describe Reference Variability.

Patterns of environmental variation do exist. For example, the cycle of cooling and warming global temperatures called the *Milankovitch cycle* repeats every 100,000 years, precipitating other waves of patterned environmental changes in its wake.

However, some environmental variables may combine and permutate in singular ways, producing trends that have no pattern over time or space. These unique trends may repeat only over a long elapsed time — or may never repeat. For instance, the seasonal distribution of solar insolation has changed since the last ice age: essentially, 9,000 years ago summers were hotter, and winters colder. Plant species individually responding to these multiple changes gave rise to unique associations.

There may, therefore, be no past analogs on which to base Reference Variability that are completely applicable to current and future conditions. If this is so, then Reference Variability will have to be derived from the best scientific understanding of sustainable trends of factors affecting Environmental Indicators and the ecosystem as a whole.

The focus for deriving Reference Variabilities needs to be on temporal scales that yield trends applicable to existing Ecosystem Elements. This may require narrowing the temporal scale of analysis to that which is most relevant to the processes currently affecting each Environmental Indicator. Inappropriately long time scales will ascribe too great a variation to the Environmental Indicator; consequently sustainability may not be served.

Ecosystems fluctuate because of internal dynamics, but generally stay within predictable bounds unless disturbed by external factors. These dynamic equilibrium conditions are a source of variability most readily discerned by examining large scales. The concept of patch dynamics is an example of a terrestrial landscape feature in dynamic equilibrium as a result of disturbance and succession (see the Chapter 2 discussion on landscape pattern). As another example, at any given point in time, individual watersheds within a river basin may exhibit very different conditions due to variation in the timing of disturbance events (such as fires or floods) among watersheds. However, over a longer time period, the individual watersheds may all cycle through the same set of conditions. They would consequently have the same Reference Variabilities for various Environmental Indicators.

Data Sources and Analysis Techniques

Numerous data sources and analysis techniques are available for describing the biological, physical, and cultural/social conditions that existed tens, hundreds, or even thousands of years ago. Data for deriving Reference Variability for Environmental Indicators can be extracted from two general sources.

- Historical conditions based on written records, photos, verbal accounts, previously conducted surveys or analyses; and field data collected from fire scars, lake sediment cores, etc. The term *historical data* will be used to refer to data from any time in the past, to the present - regardless of how long ago they may have originated.
- Current conditions based on field data collected from *Reference Areas* may be used to describe the areas as they existed in the past. Reference Areas are proxies for historic data, employed when historic data are lacking or inadequate (see Reference Areas section below).

Historical Data Sources and Methods

For decades scientists have had ways to reconstruct how past environments changed over long periods of time. Analysis of data such as fossil pollen, fossil plants and animals, radio isotopes, tree rings, sediments, archaeological deposits, and historic records has revealed a range of landscape dynamics and changing climate throughout the earth's history, especially over the past 20,000 years. Much of this information is useful for understanding the conditions which have influenced and produced our current ecosystems. Some historic data sources and methods of collection are listed and described below.

Archaeology

Archaeology uses a variety of techniques and measures to construct descriptions of past human communities and the environments in which people lived. Chronology/Seriation is one of many techniques used for dating; it uses classification and typology of artifacts to establish relative chronologies. Artifacts such as obsidian points, pottery shards, structures, fire pits, and garbage dumps can provide an array of materials that are useful for dating events and documenting the occurrence and status of components (e.g., plants, animals, water, minerals) and processes (e.g., fire, flood). Archaeobiology is one branch of archaeology, and it uses a variety of methods (e.g., pollen analysis) to establish prehistoric floral and faunal associations and changes in their distribution and composition over time.

Archival Records

Descriptions of human activities and ecological conditions from archival records provide valuable data. Historical information on social and economic conditions can also be obtained from public and private archival records. Archives can include official reports, news clippings, maps, plans, survey data and newsletters. For example, land survey records can reveal species composition, successional status, and frequency of disturbance in areas traversed and described by early surveyors. Many federal, state and local agencies have archival records that are available on request.

Dendrochronology

Stump Ring Counts may be used to determine fire history based on fire scars. Tree ring fire scar analysis via increment cores can determine the history and ecological influences of fire. Tree-ring dating can yield a record of climate and moisture cycles, and provide temporal data on floodplain formation, flood disturbance history, and landslide frequency. Interpretation of these data enables the estimation of frequencies of historical flooding and mass wasting events. Relevant temporal ranges for this kind of analysis can vary from a few years to hundreds or even thousands of years, depending on the Environmental Indicator and the longevity of the tree species used for analysis. Tree-ring analysis is widely used in archaeology to date human occupations.

Diameter Frequency Distribution and Diameter Age Regressions

This technique analyzes the frequency and intensity of natural disturbance in forested stands through diameter frequency distributions, diameter age regressions, and analysis of radial growth patterns.

Ethnography

Ethnography documents living cultures by participant observation and key informant interviewing. In conjunction with cultural ecology, it can reveal the interaction among cultural styles and technologies and the natural world. Ethnobiology is a related field of study that deals with the way that plants and animals are treated and used by different cultures. Ethnographic inquiry can yield valuable information about the stewardship skills, ancestral rights, cultural needs, cultural landscapes (e.g., important plant and animal species and uses), and a sense of place for various peoples.

Floral and Faunal Evidence

Two data sources are available. The first is field evidence: floral composition can be derived from pollen and charcoal embedded in lake sediments and other fossilized plant parts. Long-lived plants often can provide evidence of climatic changes and events (e.g., tree rings reflect growth conditions and fire occurrence; see Dendrochronology). Evidence of faunal composition is primarily gathered from skeletal remains and fossilized dung. Much of the existing evidence has already been gathered and large scale temporal and spatial changes in plant and animal abundance and distribution within California (i.e., biogeography) have been charted. The second data source consists of identification of animal remains in association with archaeological sites (see Archaeology).

Geologic Layer and Ash Analysis

Knowledge of the dates of past geologic events combined with the location of charcoal in an earth core can be used to reconstruct disturbance histories for past millennia.

Governmental Statistical Records

Information on historic social and economic conditions, human interactions with the environment, and long term trends can be found in publications by governmental statistical agencies, such as the U.S. Census and the California Statistical Abstract.

Lithic Analysis

This procedure uses stone tool construction styles and techniques to determine time periods.

Obsidian Hydration

To establish the relative dates of occupation or other events in an area, thickness of the hydration layer in obsidian is measured.

Obsidian Sourcing

Again using obsidian, x-ray fluorescence is used to determine the source of obsidian pieces, helpful in mapping migration and trade routes.

Oral History

Through oral history interviews, data not typically found in more official records or photographs may be obtained. For example, interviews with longtime local residents can yield valuable information pertaining to ranges of stream flows and animal occurrence and abundance. Information on historic social and economic conditions may also be obtained through interviews, surveys, and public participation activities.

Peat Bog and Lake Bed Analysis

Pollen and charcoal from lake bed or peat bog cores can be analyzed to reconstruct past climates and vegetation. Pollen analysis and plant macrofossils can be used to recreate the existing vegetation at various prehistoric time scales.

Photographic Studies

The effects of environmental disturbance and human activity on the landscape can be documented by comparing historical photographs with contemporary views. Photographs are also useful for documenting current conditions for future reference. Repeat photography, taking photographs from nearly identical points, can provide important comparative data. Aerial photographs document changes in vegetation over the landscape, such as pattern, amount by seral stage, and patch size. This technique only provides discrete images of ecosystem conditions.

Radiocarbon Dating

Analysis of Carbon 14 levels in organic matter can help establish the age of a site, the date of archaeological deposit, or the timing of an ecological condition or event.

Sediment Analysis

This technique uses thin sections of varved lake sediments and compares them to fire scar records to determine the accuracy reflected in fire regimes over the centuries. Lake sediments may also be used to reconstruct pre-historic fire records and to evaluate glacial advances and retreats.

Soils/Geomorphological Analysis

The structure and genesis of landforms can be determined by analyzing the chemical and structural characteristics of soil and rock formations.

Stand Composition and Age Class Analysis

Tree bole increment cores from a variety of species and size classes can be used to decipher disturbance regimes for stands along a transect. Stumps and burned trees can also be analyzed to develop a fire frequency type.

Statistical/Spatial Analysis

Mathematical techniques may be used to determine population variance, probability types, reliability of hypotheses, and inter- and intra-site variability. Geographic Information Systems (GIS) are useful tools to analyze and depict ecosystems over time and space. For example, the effects of settlement and fire suppression on the landscape can be simulated using historic data on fire sizes and return intervals. Maps of vegetation by seral stage and type can be projected through time to examine the amount, patch size, edge, and distribution characteristics at various points in the past, as well as potentials for the future.

Vegetation Mosaic Pattern

Existing vegetation mosaic and known human influences can be used to reconstruct the frequency and extent of stand replacing disturbance events over time.

Reference Areas

Reference Areas are valuable as proxies for historical conditions (i.e., "swapping space for time") to help derive Reference Variability values when historical data are incomplete, unclear, or unavailable. Reference Areas are places where disturbance regimes and ecological processes have been minimally changed over the past 100 - 200 years. They may be located outside of the analysis area if necessary. For example, if you must determine the Reference Variabilities for a dammed stream, you could look at a free flowing creek with the same environmental characteristics as the dammed creeks in the analysis area. There are limitations, however, in using reference areas as proxies, some of which include:

- they reflect only existing conditions which provide one snapshot in time;
- most ecosystems are no longer subject to characteristic disturbance events, so Reference Areas are not an entirely accurate reflection of past condition;
- the time period since the last major disturbance event will vary, which affects the occurrence of extreme values for Environmental Indicators (i.e., recent disturbance = presence of extreme conditions, no recent disturbance = potential lack of extreme values); and
- considerable time lags can occur between the occurrence of a disturbance event and the effects on the ecosystem, both in terms of initial changes and ultimate recovery.

These limitations can be minimized by sampling a large number of Reference Areas to increase the likelihood that temporal and spatial variability is best represented in the Reference Variability estimate.

An important consideration in the use of Reference Areas as a substitute for, or an addition to, historic data is that appropriate areas may be limited in size or number. In some geographic locations, Reference Areas for a given ecosystem (e.g., chaparral or flood plain/marshes) may no longer exist. Wilderness areas can be excellent Reference Areas for alpine ecosystems, but they have limited utility as proxies for lower elevation ecosystems.

Data Collection

Numerous factors must be considered in designing sampling schemes. To collect the data needed to determine Reference Variability, the two most important considerations are scale and stratification.

Scale

The first step in describing Reference Variability for an Environmental Indicator is determining the ecologically relevant temporal and spatial scales. Values for Reference Variability are dependent on the scales chosen for analysis. The area over which

samples are gathered not only needs to be ecologically relevant, but it also needs to be large enough to represent the variability that exists at a given scale. For example, Reference Variability values for the dominant substrate particle size in headwater stream channels (order 1-3) derived solely within a subwatershed may be sufficient to obtain a valid Reference Variability value. However, for streams of a higher order (order 3-5), expanding the spatial analysis to an entire watershed or river basin may be required to yield a sufficient array of similar streams for analysis.

The following items are a short list of considerations in choosing appropriate scales for analysis.

Temporal Variability

Understanding and characterizing temporal variability typically requires looking at the environment from a large spatial and long temporal scale, particularly to facilitate subsequent steps of the analysis, such as determining Recommended Management Variability. For a given analysis area, the appropriate scales are likely to vary among Environmental Indicators. For example, the appropriate temporal scale for one Indicator might be ten years and for another it might be 300 years.

Land Ownership

Both public and private lands should be considered for incorporation into data collection and analysis.

Disturbance Regimes

Sampling throughout an area affected by similar disturbance regimes is important. The geographic distribution of a given disturbance regime for a particular Environmental Indicator may determine the geographic limits of the sample area for deriving Reference Variability values.

Spatial Variability

The spatial scale to which the Reference Variability value applies should be the same scale (or area) in which the data are collected. That scale may vary, however, among the selected Indicators.

Ecological Processes

Temporal and spatial scales should reflect the ecological process of the Environmental Indicators (e.g., population fluctuations, succession) and reciprocal environmental effects that influence the Indicator (e.g., disturbance regimes, climate).

Data Quality

Appropriate temporal and spatial scales are crucial to understanding the adequacy and quality of available data.

Data Sources

It is important that data sources provide information across as broad an area as possible within the analysis area such that Reference Variability values are representative of the entire area.

Stratification

This section describes some examples of major environmental features that may affect how sampling is arrayed spatially and how data are aggregated for analysis to derive Reference Variability values. The process of stratification is separate from the process of identifying Key Ecosystem Elements and Environmental Indicators. However, some of the same categories (components, structures, and processes) can be used in both. The primary purpose of stratification is to increase precision and to avoid comparing or including unlike things (e.g., bananas and watermelons) in the derivation of Reference Variability.

If the Element of interest falls naturally into several subdivisions, or strata, sampling (i.e., field data collection) should be divided among strata. The environment can be stratified into parts that are ecologically distinct, relatively homogenous, and likely to have unique adaptations and responses to environmental change. Strata are environmental influences such as geology, climate, aspect, income bracket, and population characteristics. When collecting historical data in the field, it is important that sampling yields statistically valid information that can describe individual strata and differentiate among strata.

Stratification will generally increase the number of samples needed to yield a precise estimate of the variability that exists, so that Reference Variabilities are meaningful and useful. For example, sampling to derive Reference Variability values for pool volume across a basin in a fluvial ecosystem would involve stratifying streams by gross geology (granitics vs. ultramafics), gradient (headwater vs alluvial), stream order, as well as by channel type (confined vs braided).

Sample sizes must be large enough to describe each strata adequately. Large geographic areas are often required to obtain a sufficiently large number of replicate samples. Therefore, stratification of the environment by various features will increase the total number of data points needed to adequately describe the area by strata. Without adequate stratification, data will reflect inflated and meaningless variability.

Some examples of the types of components, structures and processes that are frequently used in stratification for sampling are listed below by ecosystem hierarchy. They represent only a subset of potential environmental parameters to be considered when stratifying samples.

- Terrestrial Hierarchy strata commonly include aspect, soil, climatic stability, disturbance regime, elevation, and vegetation series.
- Hydrologic Hierarchy strata commonly include geologic formations, hydrologic regime, and landform and channel type.
- Atmospheric Hierarchy strata commonly include elevation, distance from point source, scale.
- Cultural/Social Hierarchy strata commonly include settlement pattern, political boundaries, demography, population density, and income.

Conclusion

The full scope of Reference Variability can be difficult to derive from historical data. Historical data are rarely comprehensive spatially or temporally, and physical evidence of variation occurring over long periods of time can be difficult to detect, quantify, and classify from limited data, especially for systems that are dynamic. In many instances, a Reference Variability must be constructed from a multitude of data sources, inference, and professional judgement. Appendix B demonstrates how a range of information types can be used to develop Reference Variabilities for a suite of Environmental Indicators.

Both historical data and the use of Reference Areas as historical proxies have limitations in terms of reflecting the full range of variability that existed over hundreds or thousands of years. However, they contribute significantly to a greater understanding of the dynamics of past and current trends needed to sustain ecosystems. Without an understanding of historical and contemporary ecosystem processes, any attempt to make recommendations related to the future management of National Forest lands will be inadequate.

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Appendix A

Key Ecosystem Elements and Environmental Indicators

Table of Contents

Appendix A

Table of Contents

continued

Appendix A
Key Ecosystem Elements and Environmental Indicators

Nature has given us the seeds of knowledge, not knowledge itself.

Lucius Seneca

The concept of Key Ecosystem Elements is introduced in Chapter 2 of the Conceptual Framework. Key Ecosystem Elements are measured using Environmental Indicators and are particularly helpful in determining Reference Variability, Recommended Management Variability, and desired condition. As such, this appendix organizes some commonly used Elements into matrices. These matrices show interrelationships between Elements and how their measurement differs among scales. The Key Ecosystem Elements and their Environmental Indicators listed in this appendix are by no means exhaustive. They are suggestions upon which to build and expand.

The Key Ecosystem Elements represented here are grouped according to hierarchy. A matrix is provided for four Atmospheric, eight Cultural/ Social, 10 Hydrologic, and 14 Terrestrial Elements. Each Element's matrix includes the respective hierarchy's scales and an explanation with a brief description, its relevance to other Elements, how it is affected by other Elements, and the Environmental Indicators used to measure it. Elements are listed alphabetically within each hierarchy, except for the cultural/social, which has a logical order. In each of the four sections below, all Elements are summarized by title, category, and description; matrix tables for the hierarchy follow these narratives.

Descriptions of Key Ecosystem Elements for the Atmospheric Hierarchy

Nitrogen Oxides (Component)

Nitrogen oxides are compounds produced by natural sources and combustion of fossil fuels. In its elemental form, nitrogen is the most abundant (70%) component of air. Nitrogen compounds are produced and cycled through the atmosphere by a variety of biological and physical routes. After decomposing, organic components of the soil release nitrogen compounds into the air through biotic and abiotic nitrification. Combustion of fossil fuels, however, emits far more of these molecules, particularly when the temperatures are very high.

Atmospheric nitrogen oxides are measured by concentration, duration, and timing. Nitrogen is an essential macronutrient of all plants. Although elemental nitrogen is prevalent, it must be converted to certain molecular forms via the nitrogen cycle for plant uptake. Increasing nitrogen in deficient areas can stimulate plant growth; however, it can weaken plants at high levels. Elevated and long term deposition from atmospheric sources can affect soil biota by reducing resistance to other stressors, injure

conifers by inducing toxicity, and eutrophy streams and lakes by stimulating algal growth.

Ozone (Component)

Atmospheric ozone results when nitrogen oxides and hydrocarbons from either natural sources or combustion of fossil fuels are photochemically oxidized. Concentrations of ozone in the lower atmosphere vary depending on the amount of source emissions, the time of year, and local or regional meteorology. Ozone is measured in parts per million.

Elevated ozone levels can cause foliar injury, decrease leaf longevity, and reduce plant growth. Sensitivity to ozone differs between species. This can result in changes in plant community composition, loss of sensitive genotypes, and greater susceptibility to other stress agents, such as drought, fire, insects and pathogens. Lichens are very sensitive to ozone, and population declines can impact nitrogen fixation, soil stabilization, rock weathering, and primary succession. Lichens are also an important food source for some animals.

Particulates (Component)

Sources of particulate matter include dust, pollen, volcanism, fire and urban development. Levels of atmospheric particulate matter are quantified by the amount suspended, duration or residence time over threshold values, and the size of the particles. Generally, particulates less than 10 microns in diameter (PM10) are most important and are measured in micrograms per cubic meter.

Particulate matter in the atmosphere scatters light and reduces visibility. Urban and industrial sources of PM10 affect visibility, as does smoke from prescribed burning and wildfires. High levels of particulate matter affect the health of humans and other animals.

Sulfur Dioxides (Component)

Sulfur dioxide and sulfates are produced from natural sources and combustion of fossil fuels. Natural sources of atmospheric sulfur compounds result from vulcanism, smoke, plant and animal decay, and by-products of organisms which use sulfur compounds as an energy source. Smelters and organic fueled power plants increase atmospheric sulfur concentrations and deposition of sulfur compounds. Yearly deposition is measured in the amount deposited per unit area per year. The amount of sulfur that a terrestrial system can tolerate depends on soil leaching rates, presence of divalent cations like calcium and magnesium in the soil, mineral weathering rates, and plant species growing in the area.

Sulfur is an essential plant element; however, high levels of atmospheric sulfur affect both terrestrial and aquatic ecosystems. Sulfur is a component of amino acids in all biota, but plants may exhibit physical injury if high concentrations of sulfur oxides are transformed into sulfuric acid. Additionally, elevated levels of atmospheric sulfur, such as that contained in acid precipitation, can increase the acidity of lakes and streams. Although impacts from water body acidification are most profound in northeastern North America and Europe, monitoring water chemistry in mountain lakes with low buffering capacity and species demographics of indicator organisms is warranted.

Descriptions of Key Ecosystem Elements for the Cultural/Social Hierarchy

While the human system can be defined by its Key Ecosystem Elements, the Elements themselves overlap and are fully interrelated. The dynamic interactions between these Elements are as important as the Elements themselves. Attitudes, beliefs, and values lead people to choose certain lifestyles or lifeways. Lifestyles are structured through social organization. This structure is often reflected in land use patterns. Lifestyles and land use patterns are reflected in demographics. Economics may change attitudes and values, may set limits on lifestyles, and then be reflected in land use patterns.

Attitudes, Beliefs, and Values (Component)

This component includes the feelings, preferences, expectations, views, convictions, and concepts held by individuals, groups, and communities of people based on custom, tradition, and life experience. The sum of these values makes up one's cultural identity. Attitudes, beliefs, and values are expressed in public concern for visual quality; religious and spiritually significant sites, locations, landscapes, and areas; feelings of a sense of place; history and historic sites; and physical, emotional, and spiritual renewal. Important components of these feelings include people's sense of personal freedom, self-sufficiency, and control over their future. Examples that relate to land management include: the desire to enjoy a forest's aesthetic qualities or to utilize its resources; preferred or unwanted management practices; and, the desire to preserve familiar, sacred, archaeological, and historic sites.

Forest and wildland settings have particular emotional and symbolic meanings to many people. American Indians and other cultural groups use National Forest sites for spiritual renewal and cultural observances. Redwood groves, trails, firewood, Christmas trees, high country, solitude, wind in the treetops, glacial polish, streams, landscapes, and wildlife can all be significant to people.

Attitudes, beliefs, and values govern and shape human behavior (i.e., relationship to the land). Through these components, people define desirable resource goals, acceptable resource management (biological, physical, cultural), and quality of life. Values, traditions, morals, and convictions are frequently translated into law and policy.

Lifestyles and Lifeways (Component and Structure)

Patterns of work or means of sustenance and leisure; customs and traditions; and relationships with family, friends, and others are aspects of lifestyles and lifeways. Lifestyles involve aesthetic and amenity activities such as recreation. Lifeways involve economic and subsistence activities, occupations, traditional resource uses (e.g., hunting, gathering), and commodity production and consumption.

Lifestyles and lifeways are important contributors to quality of life (satisfaction level) and well-being. They are reflected by land use and settlement patterns, and are directly linked to effects on resources and environments to the extent that humans manage, manipulate, enhance or stress the biophysical systems.

Social Organization (Structure)

The social environment is comprised of interactions between individuals and aggregates. It has evolved from the relatively simple to the highly complicated, thus leading to the need for increasingly complex organization. Social hierarchy is thought to be a fundamental part of the human environment; this is not to equate hierarchy with social stratification, but rather recognition that a social organization is only understandable in terms of the larger context (Young 1992). Social organization manifests itself in institutions, communities, and legal constructs.

Social organization provides networks and structures for accomplishment and adaptability. It is necessary for human life and meeting basic human needs. This structure provides the means for maintenance of order and is the vehicle to support and further human beliefs and behavior.

Invention and Diffusion (Processes)

Invention is the process of creating a new idea or modifying an old idea through ingenuity, experimentation, or contrivance, and transforming it into a physical product or intangible entity (cultural traits or concepts, stories, music, etc.). The inventor may or may not have consciously been seeking invention, and it is often a combination of factors, curiosity, experience, and necessity, that leads to invention. The Forest Service, in its land managing role, often serves as the inventor of things (Pulaski tool, plant hybrids, wood products), methodologies, technology, and techniques (silvicultural techniques, information transfer).

Diffusion is the process by which invention is transmitted from one individual or group to another (Fagan 1975). Social organization plays an important role in the diffusion of inventions and innovations. The diffusion process varies considerably in distance, distribution, and length of time. Often modification of the original invention takes place throughout the diffusion process.

Invention and diffusion are key to cultural change (Beals and Hoijer 1971) and succession. Invention can result in social and political change, settlement and subsistence changes, technological change, etc., and these changes are most observable at the community and larger scales.

Land Use and Settlement Patterns (Structure)

Land use and settlement patterns range from individual households or activity areas to large regional, economic, or political networks. The intensity and distribution of land uses form a continuum of types, varying from urban, to rural, to wildland. Land use and settlement activities result in cultural landscapes. These patterns are most relevant at larger scales and have an important temporal dimension (historic, current, and future).

Land use and settlement patterns reflect structure of communities; record uses (including historic and human population influences on ecosystems); reflect human resource needs and desires; and provide information on historic population levels (landscape to subregion).

Population Characteristics (Structure)

Population characteristics are generalizations used to describe groups of people. Measures used to generate these descriptions include size, rate of change, composition (including diverse cultures, ethnic backgrounds, races, and abilities), and distribution of populations, and demographics. The diversity, number, complexity, and distribution of these characteristics increase as scale increases.

Population characteristics are the primary determinant of effects on resources and ecosystems. Diversity of population characteristics is essential to stability and cultural survival (Wolanski 1989). Population growth is a critical factor that is likely to produce total effects greater than a simple sum of individual factors combined. When linked to human need for food, water, energy and many other resources, the effects of population growth are synergistic (Myers 1993).

Economics and Subsistence (Processes)

Economics and subsistence are the processes by which people use resources. People use resources for their own consumption (subsistence), or in the production of resource based goods and services that are traded with others. The processes of production and trade cause costs to be incurred and create income and employment opportunities. The distribution of resource consumption,

production, trade, costs, income, and employment among social groups and individuals is as important as total quantities.

Resource management capability is largely determined by allocation of funds. Management activities that do not directly support subsistence uses, nor the production of goods and services that generate income and employment, are typically not favored in the appropriations and budgeting processes. Citizens, through their elected representatives, are generally less willing to tax themselves to pay for costs not directly related to providing resource uses desired by people. Moreover, opportunities for consumers to cover management costs themselves through contracts and permits are limited.

Protection of life and property, and amenity and commodity resource use are dependent on economic and subsistence processes. Additionally, these processes also support lifestyles and social organizations.

Material Culture (Component and Structure)

Human ecology includes not only the intangible components, structures, and processes made up by humans and resulting from human interaction, but the tangible things people make or shape for their use and the physical environments they create for themselves. Material culture is a direct reflection of patterned human behavior. The components of this environment consist of artifacts, including tools, personal and ceremonial objects, etc., and a variety of physical structures and buildings. They include the shaping of biological elements for human use such as the development of hybrids or domesticates, or the organization of plants into a garden, or even the cultural shaping or manipulation of the human body itself (Deetz 1977). Many of these components are combined or used together to form structures, such as community and intercommunity complexes with their associated infrastructure and landscapes. Land use and settlement patterns show how these are organized hierarchically.

Material culture is the means by which humans meet environmental and psychological needs. Material culture is the physical evidence of human behavior and activity. Artifacts and archaeological assemblages provide important data about past cultures when other resources are unavailable, such as ethnographies and written records. Material culture can reveal information about seasonal settlement patterns, adaptation to different environments, diverse groups of people and their distribution, and cultural change.

Descriptions of Key Ecosystem Elements for the Hydrologic Hierarchy

Aquatic Animal Species (Component)

The ecological role of aquatic animals (vertebrates and invertebrates--macro and micro) is evaluated using the animal species element. Fish, amphibians, insects, crustaceans, and molluscs are examples of aquatic animal species evaluated. This Element is described by the presence, abundance, distribution, and population demography of animals. Abundance and distribution can be described at many scales.

Animal and plant species are both the substance and measure of biological diversity. They are not just dependent upon environmental factors for their survival. Animal species alter the environment in countless ways, some subtle and some dramatic. Aquatic and terrestrial animal species are often interrelated, in that they affect one another through food webs and nutrient cycling. Many other Key Ecosystem Elements affect animal species, and these relationships are displayed in the matrices.

Channel Morphology (Component and Structure)

Channel morphology refers to the shape and structural features of a stream channel. Morphological features most important in influencing aquatic habitat conditions are pool/riffle ratio, channel bank steepness, as well as channel width, depth, and gradient. These features are influenced by local geology and climate which can determine the amount and size of sediment, the duration and size of peak flows, stream gradient, and channel bank steepness. Morphological features most significant in influencing aquatic habitat conditions are: 1) pool parameters; 2) channel width and depth; and, 3) bank steepness & stability. Pools are essential to fish because they provide a range of habitats, store nutrients for food, and act as buffers during sediment pulses. The frequency and size of pools are dependent on stream size, gradient, confinement, large woody debris, flow and sediment load. Land management activities, as well as natural disturbances, can change the frequency and size of pools via altered sediment loads and organic debris. Residual pool depth, area, and volume of pools can serve as sensitive indicators of changes in sediment load.

Channel width and depth is an important parameter to monitor. Management activities and natural events can cause channel aggradation, reduced pool depth, loss of pool habitat, an increase in summer temperatures, decrease in winter temperatures, reduced stream cover, and a reduction in invertebrate production.

Bank steepness and stability can be an important indicator of the condition of a given stream or watershed. Unstable banks contribute sediment to the stream by slumping and surface erosion, causing corresponding decreases in depth, which may raise maximum summer temperatures and reduce cover for fish. Further, actively eroding stream banks support little or no vegetation, which can reduce both input of organic matter and habitat for other riparian dependent species.

Flooding (Process)

Flooding occurs when water exceeds the bankfull portion of a channel and overflows on to the adjacent floodplain. It is a natural process that occurs with varying degrees of frequency, duration, and magnitude. Periodic small scale floods that occur 2 - 3 years apart are important for channel maintenance by revitalizing the channel by scouring, redepositing bed material, and increasing nutrients available for aquatic production. Floods can also reposition large woody debris that help form pools, provide cover for young fish, and release nutrients for stream productivity.

Large floods can cause heavy sedimentation of streambeds and damage to channels. If stream bank vegetation has been altered or removed, a stream compensates for a flood by adjusting its channel width, resulting in over-widening and infilling of pools with sediments. When these adjustments take place, fish and other aquatic animal populations usually decline. Large floods can also trigger landslides and debris torrents in steep terrain which can further cause stream aggradation and loss of aquatic habitat via sedimentation of pools and riffles.

Food Web (Component and Structure)

Food web refers to the network of interdependent organisms making up the biotic component of a nutrient pathway. Food webs are paths by which nutrients are exchanged among organisms. Methods of nutrient exchange include predation, mutualism, parasitism, decay, agriculture, and all other relationships which facilitate exchange of nutrients between organisms.

Net primary productivity and phytoplankton/zooplankton productivity can be measured to estimate individual components of the food web. Terrestrial and hydrologic food webs are interconnected.

Hydrologic Cycle (Process)

The hydrologic cycle encompasses all processes by which water moves around the earth. The cycle includes precipitation, evaporation, transpiration, surface run-off and storage, infiltration, percolation, and groundwater flow and storage. Water cycles influence many aspects of aquatic systems, including fluvial geomorphic processes such as sediment routing. Further, it influences almost every aspect of terrestrial ecosystems. By compiling measures of the individual cycle components, estimates of the overall hydrologic regime can be made.

Nutrient Pathways (Process)

Nutrient pathways refer to the routes and rates of flow through an ecosystem. Nutrients can be tracked individually or collectively over time through analysis of water quality, benthic invertebrates, fish species, filamentous algae, and other plant and animal species. Nutrients are cycled both within and between the terrestrial and hydrologic systems.

Nutrient pathways intimately link the physical, biological and cultural/social aspects of the ecosystem. Nutrients necessary for biological function are converted from inorganic forms by simple plants and animals to forms that can be utilized by more complex organisms. Exchange is facilitated by movement between the atmosphere, oceans, aquatic ecosystems, and soil by physical and biological and cultural/social processes.

Organic Debris (Component and Structure)

Large organic debris can be defined as the amount and size (diameter, length, or volume) of organic material within a stream channel introduced from the surrounding riparian and upslope vegetation. Large organic debris, most commonly referred to as large woody debris (LWD) serves as both a component and structure of the aquatic ecosystem. Large woody debris influences the morphology of many small streams. It can alter channel width and meander patterns, provide storage of both sediment and bedload, and is often the most important source of pool formation in small streams. Additionally, large wood is an important source of instream cover for fish, as well as habitat for aquatic insects and herptofauna.

Plant Species (Component and Structure)

Aquatic and riparian vegetation are two categories of plants within this Element. Aquatic vegetation is composed of plants growing within bodies of water. It may be submerged, emergent, or floating. Riparian vegetation is defined as the vegetation growing on or near the banks of a stream or other water body on soils that exhibit some wetness characteristics during some portion of the growing season. The type and amount of riparian vegetation present is an influence on stream temperatures, bank erosion, and aquatic habitat.

Riparian vegetation has many direct and indirect influences on channel morphology, water quality, and fish habitat. Riparian vegetation provides varying degrees of shade depending on the size of the stream, the surrounding valley steepness, the vegetative response to periodic flooding, and water tables. Besides providing energy to the stream system and buffering the supply of both sediment and nutrients to stream channels, it provides habitat for aquatic organisms with non- or semi-aquatic life stages. The ability and availability of the surrounding riparian zone to provide future woody debris is critical for habitat diversity and complexity.

Sediment (Component and Structure)

Sediment is the product of soil erosion that makes its way into a channel. Sediment is comprised of both the suspended particles within the water column (suspended sediment), as well as the substrate residing along the bed of a stream channel

(bed material). Material is moved during high flows by bouncing and rolling along the channel bed (bedload). The relative size of particles transported as bedload or suspended load will vary with the flow regime, channel morphology, and size and type of material.

The composition and structure of material within a channel is an important indicator of aquatic habitat quality. The particle size of the bed material directly affects flow resistance in the channel, stability of the stream bed, and amount and quality of instream habitat. A disproportionate percentage of fine particles can affect the amount of microhabitat available for juvenile fish and for macroinvertebrates by filling up the interstitial spaces between coarse particles. Additionally, increased deposition of fine particles may be partially self-perpetuating, because once they fill in the crevices between larger bed material, fine particles act as an armor which delays bedload movement during high flows. A reduction in bedload transport, then, provides more opportunity for additional deposition of fine particles and less opportunity for flushing out during high flows.

Water (Component and Structure)

Water as structure refers to the distribution and flow of water across landscapes. At small scales water is distributed in ponds, springs, bogs and subsurface flow. At larger scales it is distributed in drainage systems, lakes and aquifers.

Water as a component refers to water quality and quantity which are important indicators of ecosystem condition. Stream temperature and amount and duration of flow have been extensively studied and their importance to instream biota and habitat documented.

Water temperature is influenced by radiation input, evaporation, convection, conduction and advection, and varies seasonally as well as diurnally. Increased water temperature is known to influence the behavior and survival of aquatic biota. Disturbances in the riparian vegetation can alter the solar radiation input and increase stream temperatures. In particular, salmonid egg and alevin development have been shown to be closely associated with stream temperatures.

Descriptions of Key Ecosystem Elements for the Terrestrial Hierarchy

Terrestrial Animal Species (Component)

The ecological role of terrestrial animals (vertebrates and invertebrates--macro and micro) is evaluated using the animal species element. Mammals, birds, amphibians, reptiles, and insects are examples of animal species evaluated. This Element is described by the presence, abundance, distribution, and population demography of animals. Abundance and distribution can be described at many scales.

Animal and plant species are both the substance and measure of biological diversity. They are not just dependent upon environmental factors for their survival. Animal species alter the environment in countless ways, some subtle and some dramatic. Many ecosystem elements affect animal species, and these relationships are displayed in the matrices.

Damage (Process)

Damage to plants caused by windthrow and storms may be significant. Windthrow can cause dispersed mortality of individual trees or groups of trees. It most commonly occurs at exposed locations such as ridges or edges of openings. Windthrow is also more prevalent among shallow rooted species or in areas where rooting is restricted by water table or soil layers.

Storm damage can cause widespread breakage of trees or other vegetation. The result is an increase in coarse woody debris, sometimes over large areas.

The influence of windthrow and storm damage is estimated by describing their distribution, frequency, return interval, predictability, area and magnitude over time.

Results of storm damage as well as other environmental agents may have important influences on other Elements. Areas affected by damage may provide an opening in the forest beneficial for plant regeneration or wildlife habitat. The consequent addition of organic debris to the forest floor can enhance soil productivity , increase fuel loads, and improve terrestrial and aquatic animal habitat.

Erosion (Process)

Erosion can be defined as the processes by which material (rock, soil) is removed from a surface by moving water, wind, glaciers, or freeze-thaw action. Erosion can be classified either as mass movement (landslides, debris torrents, earthflows) or as surface erosion (sheet, rills, gullies). It can be measured by estimating the amount of material lost from the site, or it can be calculated using mathematical equations.

The potential for surface erosion is directly related to the amount of bare, compacted soil exposed to rainfall and runoff. Surface erosion by sheetwash, rilling, or gullying can remove valuable topsoil, and extensive gullying can lower the water table; the net result of these processes is reduced vegetative productivity of a site. Displacement of fine soil particles can have negative downstream impacts on aquatic ecosystems through sedimentation.

Where forest and rangelands occur on steep terrain, mass soil movement is often the primary mode of erosion and sediment delivery to streams. Mass soil movements (landslides, debris torrents and flows) usually occur when these soils are saturated with water. When earthflows reach streams, they bring large quantities of sediment to the channel and may scour the streambed down to bedrock. Large slope failures may dam streams temporarily or permanently, thus altering channel morphology and flow regime.

Fire (Process)

Fires ignited from any source can alter many components, structures and processes of ecosystems. The influence of fire is estimated by describing its distribution, frequency, return interval, predictability, area, and magnitude over time. Seasonality of occurrence during the year is an important feature since fire interacts with biota differently depending on life stage and carbohydrate reserves. The effects of individual fires are measured by severity and distribution of severity across the landscape. The various Environmental Indicators for fire must be combined geographically to get a complete picture of the fire regime. Different subsets of this information are appropriate at each scale.

Fire affects all terrestrial, hydrologic, atmospheric and cultural/social elements. It influences the distribution of plants and animals in several ways depending on its frequency and intensity: accelerating or retarding the succession of seral stages on a site, making nutrients available or scarce to plants, and changing habitat structure and forage composition. Fire and decomposition are the two natural processes which regulate the removal of woody debris from the system. It is also an important agent of disturbance for watershed processes; fire exposes bare mineral soil, possibly increasing surface runoff and erosion.

Food Web (Component and Structure)

Food web refers to the network of interdependent organisms making up the biotic component of a nutrient cycle or pathway. Food webs are the essential paths by which nutrients are exchanged among organisms. Methods of nutrient exchange include predation, mutualism, parasitism, decay, agriculture, economic exchange and all other relationships which facilitate exchange of nutrients among organisms. Terrestrial and aquatic food webs are interconnected.

Genetic Diversity (Component, Structure and Process)

Genetic diversity is the source of all biological variation. It can be partitioned into composition, structure (pattern), and function (process). Genetic materials can be shuffled, packaged, and re-sorted to form new ecotypes or species as individuals interact with other elements within ecosystems. Genetic change may take place very quickly (e.g., plant hybridization) or over many generations (e.g., Darwinian finches).

Genetic diversity is the raw material of all biodiversity. Losses of populations and species can be influenced by the characteristics of the habitat (vegetation mosaics, aquatic habitat structure, water quality, organic debris, and soil productivity), as well as disturbance (fire, insect infestations, pathogens and disease, and damage).

Insects (Process)

Insects are ubiquitous biotic components that have numerous functions within ecosystems.
For example, they are important in nutrient cycling, as pollinators, and as food sources. Their importance in these regards, however, is recognized and covered under the animal species Element.
This Element focuses on the role of insects as disturbance agents; it serves to quantify and evaluate the impact of insects on the vegetation mosaic. In this limited view, the effects of those species which cause periodic disturbance by killing or reducing vigor of dominant plants are measured. The influence of insects as pests is estimated by describing its distribution, frequency, return interval, predictability, area, and magnitude over time.

Insects are an important source of disturbance in ecosystems. Insects (or combinations of insects, pathogens and disease, and fire) can cause mortality of trees, shrubs, and herbaceous plants.
Dead material and openings created provide sources of animal habitat (aquatic and terrestrial), fire fuels, seed beds, nutrients, and soil cover. The dead material may also influence water quality and channel morphology, depending on the proximity to the stream.

Nutrient Cycles (Process)

Nutrient cycles are the routes and rates of nutrient flow through an ecosystem. Nutrients enter a system through some form natural or human-caused deposition, and are converted, transferred, or assimilated. One method of estimating input is analyzing soil fertility. Nutrient cycling occurs both within and between terrestrial and hydro logic systems.

Nutrient cycling intimately links the physical, biological and cultural/social aspects of the ecosystem. Nutrients necessary for biological function are converted from inorganic forms by simple plants and animals to forms that can be utilized by more complex organisms. Exchange is facilitated by movement between the atmosphere, oceans, aquatic ecosystems, and soil by physical, biological, and cultural/social processes.

Organic Debris (Component and Structure)

Woody debris is important to all biota and assemblages of biota at different scales. Vegetative series and their seral expressions have characteristic woody debris accumulation and decay rates that are related to climate and other physical influences. Fire regimes, soil productivity, and water quality are affected by amount and distribution of woody debris. It provides habitat for both terrestrial and aquatic organisms, and is a substrate for decomposers.

Coarse Woody Debris

Coarse woody debris is all the surface organic material greater then 3 inches in diameter. Various size and decomposition classes are tracked for various elements in the ecosystem. For the purposes of wildlife habitat and soil productivity, coarse woody debris, in the form of down logs, is usually

measured in diameter classes of 10 inches or greater and 12 inches or greater, respectively. Standing woody debris (snags) is also important, but is treated separately from down woody debris.

Fine Organic Matter

Fine organic matter is material on top of mineral soil consisting of fallen vegetative matter in various stages of decomposition. It includes plant litter, duff, and woody material less than 3 inches in diameter. Fine organics can be measured using litter traps, or monitoring the depth of the duff layer.

Pathogens and Diseases (Process)

Pathogens and disease are important disturbance agents that kill dominant plants or groups of plants. The influence of pathogens and disease is estimated by describing their distribution, frequency, return interval, predictability, area, and magnitude over time.

Pathogens and disease (or combinations of insects, pathogens, diseases, and fire) cause mortality of trees or shrubs. Similar to the effects caused by insects, dead material and openings created provide sources of animal habitat (aquatic and terrestrial), fire fuels, seed beds, nutrients, and soil cover. The dead material may also influence water quality and channel morphology, depending on the proximity to the stream.

Plant Species (Component)

The ecological role of terrestrial plants is evaluated using the plant species element. Plant species include vascular plants, lichen, algae, bryophytes, and fungi. This Key Ecosystem Element is analyzed by presence, abundance, distribution, and population demographics of plants. All can be described at many scales in both the terrestrial and hydrologic hierarchies.

Plant species are dependent upon environmental factors for their survival, and in turn, modify their environment in many ways. Plants contribute most of the organic material to ecosystems, and provide habitat and forage for animals. Some plant associates, such as mycorrhizal fungi which help improve nutrient and water uptake, are also included in this element. Assemblages of plant species comprise the vegetation mosaic, which is often used to characterize landscapes. All of the other ecosystem elements affect plant species, and these relationships are displayed in the matrices.

Soil Hydrology (Process)

Soil Hydrologic Function is the inherent capacity of a soil to intake, retain and transmit water. To avoid accelerated surface runoff, infiltration and permeability should not be reduced to ratings of 6 or 8, as defined in Region 5 Erosion Hazard Rating system (Chapters 5, R-5 FSH 2509.22)

Soil Hydrologic Function is an important factor in water routing. Maintaining or improving soil porosity and infiltration will help prevent accelerated surface runoff and sustain the soil moisture regime. Infiltration, permeability, and depth to a layer of reduced permeability are interrelated factors that govern the rate of water movement into and through the soil. They are the major factors used to calculate Runoff Production Rates for computation of Erosion Hazard Ratings (FSH 2509.22).

Soil Productivity (Component, Structure and Process)

Soil productivity is the capacity of a soil to produce biomass through plant growth. Soil cover, porosity, organic matter, and moisture regime are used as Environmental Indicators of soil productivity.

Soil cover is the amount of surface area covered by tree and shrub canopies, low growing vegetation, plant litter and debris, and surface rock fragments larger than about 3/4 inches. Soil porosity is the

volume of pores in a soil sample divided by the bulk volume of the sample. Soil organic matter is the organic fraction exclusive of undecayed plant and animal residues. Soil moisture regime refers to the amount of ground water held in the soil or in specific horizons at various times throughout the year.

Soil productivity is important in establishment and maintenance of sustainable plant and animal communities. Soil cover ensures that soil will remain on the site and not be removed through erosion. Maintaining soil porosity allow free movement of water and air through the soil for nutrient cycling, soil organisms, and plant roots. Soil organic matter is important as food for organisms and for both short and long-term nutrient cycling. The soil moisture regime is important to plant growth and potential plant community composition. The growth of many plants is proportional to the amount of water present, since growth is restricted at both very low and very high soil moisture levels. Water is required by plants to manufacture carbohydrates, maintain hydration of protoplasm, and translocate foods and mineral elements. Internal moisture stress causes a reduction in both cell division and cell elongation, and subsequently, plant growth.

Vegetation Mosaic (Structure)

Vegetative mosaic is the distribution of plant species across the land. It varies spatially and temporally; horizontal and vertical distribution patterns are differentiated by defining characteristics such as species, plant communities, seral stage development, life form, density, and cover. Distribution and amount of such defining characteristics can be expressed in a number of ways including area, patch size and shape, arrangement patterns within the landscape, and vegetative matrix gaps. The defining characteristics will change in accordance with the specific spatial analysis scale used.

The vegetation mosaic is a Key Ecosystem Element when determining habitat suitability for all biological species and individuals. Plant communities and seral stages or specific habitat properties can be used as direct (floral) and indirect (faunal) measures of biological diversity and habitat suitability. Mapping mosaic patterns and analyzing occurrence and distribution along with habitat interrelationship characteristics allow assessment of habitat suitability and species viability at appropriate scales.

Vegetative density and fuels structure and distribution (location in the landscape) influence disturbance by fire, insect infestations, pathogens, and damage. The mosaic influences the type and amount of organic debris on the site influencing soil productivity through protection and nutrient cycling. Vegetation is important in reducing air pollutants and converting carbon dioxide to oxygen at larger scales. It influences aquatic systems through shading, input of nutrients, and structural components.

Matrix of Atmospheric Ecosystem Elements - Atmospheric Hierarchy

Ecosystem Element	Watershed	River Basin	Air Basin
Ozone **(Component)**	**Description** O_3 compounds produced by the photochemical oxidation of nitrogen oxides and hydrocarbons **Relevance** Cultural/Social Links attitudes, beliefs, and values; lifestyles and lifeways; social organization; economics and subsistence; material culture; invention and diffusion Hydrologic Links riparian vegetation; nutrient pathways; animal species; erosion Terrestrial Links animal and plant species; nutrient cycling; soil stabilization **Affected by** Atmospheric Links climate, nitrogen dioxide, hydrocarbons Cultural/Social Links all cultural/social elements **Environmental Indicators** concentration, duration, sensitive receptors	**Description** O_3 compounds produced by the photochemical oxidation of nitrogen oxides and hydrocarbons **Relevance** Cultural/Social Links attitudes, beliefs, and values; lifestyles and lifeways; social organization; economics and subsistence; material culture; invention and diffusion Hydrologic Links genetic diversity; nutrient pathways; animal species; riparian vegetation Terrestrial Links vegetation mosaic; genetic diversity; nutrient cycling; animal species **Affected by** Atmospheric Links climate, nitrogen dioxide, hydrocarbons Cultural/Social Links all cultural/social elements **Environmental Indicators** concentration, duration, sensitive receptors	**Description** O_3 compounds produced by the photochemical oxidation of nitrogen oxides and hydrocarbons **Relevance** Atmospheric Links nitrogen dioxide, hydrocarbons Cultural/Social Links attitudes, beliefs, and values; lifestyles and lifeways; social organization; economics and subsistence; material culture; invention and diffusion Hydrologic Links genetic diversity; nutrient pathways; animal species; riparian vegetation Terrestrial Links vegetation mosaic; genetic diversity; animal species **Affected by** Atmospheric Links climate, nitrogen dioxide, hydrocarbons Cultural/Social Links all cultural/social elements **Environmental Indicators** concentration, duration, sensitive receptors

Matrix of Atmospheric Ecosystem Elements - Atmospheric Hierarchy

Ecosystem Element	Watershed	River Basin	Air Basin
Particulates **(Component)**	**Description** minute particles of dust, coal, pollen, ash, etc. temporarily suspended in the atmosphere **Relevance** <u>Atmospheric Links</u> visibility <u>Cultural/Social Links</u> attitudes, beliefs, and values; lifestyles and lifeways; social organization; economics and subsistence; material culture; invention and diffusion <u>Hydrologic Links</u> animal and plant species; water quality <u>Terrestrial Links</u> animal and plant species **Affected by** <u>Cultural/Social Links</u> all cultural/social elements <u>Terrestrial Links</u> fire, soil	**Description** minute particles of dust, coal, pollen, ash, etc. temporarily suspended in the atmosphere **Relevance** <u>Atmospheric Links</u> visibility, climate <u>Cultural/Social Links</u> attitudes, beliefs, and values; lifestyles and lifeways; social organization; economics and subsistence; material culture; invention and diffusion <u>Hydrologic Links</u> animal and plant species; water quality <u>Terrestrial Links</u> animal and plant species **Affected by** <u>Atmospheric Links</u> climate <u>Cultural/Social Links</u> all cultural/social elements <u>Terrestrial Links</u> fire, erosion	**Description** minute particles of dust, coal, pollen, ash, etc. temporarily suspended in the atmosphere **Relevance** <u>Atmospheric Links</u> visibility, climate <u>Cultural/Social Links</u> attitudes, beliefs, and values; lifestyles and lifeways; social organization; economics and subsistence; material culture; invention and diffusion <u>Hydrologic Links</u> animal and plant species; water quality <u>Terrestrial Links</u> animal and plant species **Affected by** <u>Atmospheric Links</u> climate <u>Cultural/Social Links</u> all cultural/social elements <u>Terrestrial Links</u> fire regimes, erosion

Matrix of Atmospheric Ecosystem Elements - Atmospheric Hierarchy

Ecosystem Element	Watershed	River Basin	Air Basin
Particulates (continued)	**Environmental Indicators** concentrations, duration, sensitive receptors	**Environmental Indicators** concentrations, duration, sensitive receptors	**Environmental Indicators** concentrations, duration, sensitive receptors
Nitrogen Oxides **(Component)**	**Description** family of nitrogen and oxygen molecules (NO_x) formed in all combustion processes **Relevance** <u>Cultural/Social Links</u> attitudes, beliefs, and values; lifestyles and lifeways; social organization; economics and subsistence; material culture; invention and diffusion <u>Hydrologic Links</u> animal species, food web, nutrient pathways, plant species, water quality <u>Terrestrial Links</u> animal species, food web, nutrient cycling, plant species, soil stabilization **Affected by** <u>Cultural/Social Links</u> all cultural/social elements	**Description** family of nitrogen and oxygen molecules (NO_x) formed in all combustion processes **Relevance** <u>Cultural/Social Links</u> attitudes, beliefs, and values; lifestyles and lifeways; social organization; economics and subsistence; material culture; invention and diffusion <u>Hydrologic Links</u> animal species, food web, nutrient pathways, water quality <u>Terrestrial Links</u> animal species, nutrient cycling, vegetation mosaic **Affected by** <u>Cultural/Social Links</u> all cultural/social elements	**Description** family of nitrogen and oxygen molecules (NO_x) formed in all combustion processes **Relevance** <u>Cultural/Social Links</u> attitudes, beliefs, and values; lifestyles and lifeways; social organization; economics and subsistence; material culture; invention and diffusion <u>Hydrologic Links</u> genetic diversity, nutrient pathways, water quality <u>Terrestrial Links</u> genetic diversity, nutrient cycling **Affected by** <u>Atmospheric Links</u> climate <u>Cultural/Social Links</u> all cultural/social elements

Matrix of Atmospheric Ecosystem Elements - Atmospheric Hierarchy

Ecosystem Element	Watershed	River Basin	Air Basin
Nitrogen Oxides (continued)	Hydrologic Links animal species, organic debris, plant species Terrestrial Links animal species, organic debris, plant species, soil temperature, soil moisture **Environmental Indicators** concentration, duration, sensitive receptors	Hydrologic Links animal species, nutrient pathways, organic debris, plant species Terrestrial Links animal species, nutrient cycling, organic debris, plant species, soil productivity, vegetation mosaic, damage **Environmental Indicators** concentration, duration, sensitive receptors	Hydrologic Links animal species, nutrient pathways, organic debris, plant species Terrestrial Links animal species, organic debris, plant species, damage **Environmental Indicators** concentration, duration, sensitivereceptors
Sulfur Dioxides **(Component)**	**Description** a colorless gas, SO_2 results from combustion of fossil fuels and natural emission sources like volcanoes, fumaroles, and organic decay **Relevance** Cultural/Social Links attitudes, beliefs, and values; lifestyles and lifeways; social organization; economics and subsistence; material culture; invention and diffusion	**Description** a colorless gas, SO_2 results from combustion of fossil fuels and natural emission sources like volcanoes, fumaroles, and organic decay **Relevance** Cultural/Social Links attitudes, beliefs, and values; lifestyles and lifeways; social organization; economics and subsistence; material culture; invention and diffusion	**Description** a colorless gas, SO_2 results from combustion of fossil fuels and natural emission sources like volcanoes, fumaroles, and organic decay **Relevance** Cultural/Social Links attitudes, beliefs, and values; lifestyles and lifeways; social organization; economics and subsistence; material culture; invention and diffusion

Matrix of Atmospheric Ecosystem Elements - Atmospheric Hierarchy

Ecosystem Element	Watershed	River Basin	Air Basin
Sulfur Dioxides (continued)	Hydrologic Links animal species, erosion, food web, nutrient pathways, plant species, substrate, water quality Terrestrial Links animal species, food web, nutrient cycles, plant species, soils (stabilization, chemistry, erosion), substrate **Affected by** Cultural/Social Links all cultural/social elements Hydrologic Links animal species, food web, nutrient pathways, organic debris, plant species Terrestrial Links animal species, food web, nutrient cycles, organic debris, plant species, soils (chemistry and productivity), geology (volcanism) **Environmental Indicators** concentration, duration, sensitive receptors	Hydrologic Links animal species, nutrient pathways, plant species, water quality Terrestrial Links animal species, nutrient cycles, plant species, soil productivity, vegetation mosaic **Affected by** Cultural/Social Links all cultural/social elements Hydrologic Links animal species, nutrient pathways, organic debris, plant species Terrestrial Links animal species, nutrient cycles, plant species, soils (chemistry and productivity), geology (volcanism) **Environmental Indicators** concentration, duration, sensitive receptors	Hydrologic Links nutrient pathways, water quality Terrestrial Links nutrient cycling, vegetation mosaic **Affected by** Cultural/Social Links all cultural/social elements Hydrologic Links nutrient pathways Terrestrial Links nutrient cycles, soils (chemistry and productivity), geology (volcanism) **Environmental Indicators** concentration, duration, sensitive receptors

Matrix of Key Ecosystem Elements - Cultural/Social Hierarchy

Ecosystem Element	Individual/ Small Group	Community/ Landscape	Subregion	Region
Attitudes, Beliefs, and Values **(Component)**	**Description** individual views, concepts, life experiences, convictions, opinions **Relevance** Cultural/Social Links governs and shapes behavior and human identity; direct link to how people use, affect, adapt to or modify their environment Hydrologic Links animal and plant species, channel morphology, flooding, nutrient pathways, organic debris, water Terrestrial Links animal and plant species, fire, food web, genetic diversity, insects, vegetation mosaic	**Description** customs and traditions **Relevance** Cultural/Social Links defines and shapes resource goals and management; community identity, maintenance, and related associations with the environment may be reflected in resource goals, policies, or laws Hydrologic Links animal and plant species, channel morphology, flooding, hydrologic cycle, nutrient pathways, organic debris, sediment, water Terrestrial Links animal and plant species, fire, food web, genetic diversity, insects, organic debris, pathogens and disease, vegetation mosaic	**Description** religions, faiths, social/political trends, ethics **Relevance** Cultural/Social Links translates into law and policy Hydrologic Links animal and plant species, channel morphology, flooding, hydrologic cycle, sediment, water Terrestrial Links animal and plant species, fire, food web, genetic diversity, insects, organic debris, pathogens and disease, vegetation mosaic	**Description** religions, faiths, philosophies, social/political trends, aesthetic and other broad scale values **Relevance** Cultural/Social Links more all pervasive affects on ecosystems, translates into law and policy Hydrologic Links animal and plant species, channel morphology, flooding, food web, hydrologic cycle, water Terrestrial Links animal and plant species, fire, food web, genetic diversity, insects, organic debris, pathogens and disease, vegetation mosaic

Matrix of Key Ecosystem Elements - Cultural/Social Hierarchy

Ecosystem Element	Individual/ Small Group	Community/ Landscape	Subregion	Region
Attitudes, Beliefs, and Values (continued)	**Affected by** Atmospheric Linksall atmospheric elements Cultural/Social Links socialization, learning, and reinforcement Hydrologic Linksanimal species, flooding, hydrologic cycle, nutrient pathways, organic debris, plant species, water Terrestrial Links fire, food web, genetic diversity, plant species, vegetation mosaic	**Affected by** Atmospheric Links all atmospheric elements Cultural/Social Links political systems; environmental and economic conditions; social organization Hydrologic Links animal species, channel morphology, flooding, hydrologic cycle, nutrient pathways, organic debris, plant species, water Terrestrial Links animal, fire, food web, genetic diversity, plant species, vegetation mosaic	**Affected by** Atmospheric Links all atmospheric elements Cultural/Social Links political systems; environmental and economic conditions; social organization Hydrologic Links animal species, channel morphology, flooding, hydrologic cycle, nutrient pathways, water Terrestrial Links animal species, fire, food web, genetic diversity, plant species, vegetation mosaic	**Affected by** Atmospheric Links all atmospheric elements Cultural/Social Links political systems; environmental and economic conditions; social organization Hydrologic Links animal species, channel morphology, flooding, hydrologic cycle, nutrient pathways, water Terrestrial Links animal, fire, food web, genetic diversity, plant species, vegetation mosaic
	Environmental Indicators expression of realized expectations	**Environmental Indicators** expression and variety of expectations realized; levels of involvement, activity, harmony, and cooperation; acceptance of diversity	**Environmental Indicators** levels of involvement, activity, harmony and cooperation; recognition and incorporation of diverse values and beliefs in socio-political structure and cultural activities	**Environmental Indicators** levels of involvement, activity, harmony, and cooperation; recognition and incorporation of diverse values and beliefs in socio-political structure and cultural activities

Matrix of Key Ecosystem Elements - Cultural/Social Hierarchy

Ecosystem Element	Individual/ Small Group	Community/ Landscape	Subregion	Region
Lifestyles and Lifeways **(Component & Structure)**	**Description** individual persons/identity; households, individual or small businesses or means of subsistence; self identified groups **Relevance** <u>Cultural/Social Links</u> land uses <u>Hydrologic Links</u> animal species, flooding, food web, organic debris, plant species, sediment, water <u>Terrestrial Links</u> fire, food web, genetic diversity, plant species, soil hydrology, soil productivity, vegetation mosaic	**Description** urban, suburban, and rural components **Relevance** <u>Atmospheric Links</u> all atmospheric elements <u>Cultural/Social Links</u> community practices, land use patterns <u>Hydrologic Links</u> all hydrologic elements <u>Terrestrial Links</u> animal species, erosion, fire, food web, genetic diversity, nutrient cycles, organic debris, plant species, soil hydrology, soil productivity, vegetation mosaic	**Description** groupings of urban, suburban, and rural communities and cultures; “a western lifestyle” **Relevance** <u>Atmospheric Links</u> all atmospheric elements <u>Cultural/Social Links</u> land use and settlement patterns <u>Hydrologic Links</u> animal species, channel morphology, flooding, food web, hydrologic cycle, nutrient pathways, plant species, sediment, water <u>Terrestrial Links</u> animal species, erosion, fire, food web, genetic diversity, nutrient cycles, organic debris, plant species, soil hydrology, soil productivity, vegetation mosaic	**Description** aggregations of subregional communities and cultures; “a western lifestyle”; nations **Relevance** <u>Atmospheric Links</u> all atmospheric elements <u>Cultural/Social Links</u> land use and settlement patterns <u>Hydrologic Links</u> animal species, channel morphology, food web, hydrologic cycle, nutrient pathways, plant species, water <u>Terrestrial Links</u> animal species, erosion, fire, food web, genetic diversity, nutrient cycles, organic debris, plant species, soil hydrology, soil productivity, vegetation mosaic

Matrix of Key Ecosystem Elements - Cultural/Social Hierarchy

Ecosystem Element	Individual/ Small Group	Community/ Landscape	Subregion	Region
Lifestyles and Lifeways (continued)	**Affected by** Cultural/Social Links tradition, beliefs, and values Hydrologic Links animal species, channel morphology, food web, nutrient pathways, organic debris, plant species, sediment, water Terrestrial Links animal species, erosion, fire, food web, nutrient cycles, organic debris, plant species, vegetation mosaic **Environmental Indicators** access and availability of economic, aesthetic, educational, and recreational resources; satisfaction; maintenance of lifestyle; scenic quality	**Affected by** Atmospheric Links all atmospheric links Cultural/Social Links economic and political conditions; technology Hydrologic Links animal species, channel morphology, food web, hydrologic cycle, nutrient pathways, organic debris, plant species, sediment, water Terrestrial Links animal species, erosion, fire, food web, genetic diversity, nutrient cycles, organic debris, plant species, soil hydrology, soil productivity, vegetation mosaic **Environmental Indicators** access and availability of economic, aesthetic, educational, and recreational resources; lifestyle and use trends; diversity of lifestyles; scenic quality	**Affected by** Atmospheric Links all atmospheric elements Cultural/Social Links economic and political conditions; technology Hydrologic Links animal species, channel morphology, food web, hydrologic cycle, nutrient pathways, plant species, sediment, water Terrestrial Links animal species, erosion, fire, food web, genetic diversity, nutrient cycles, organic debris, plant species, soil hydrology, soil productivity, vegetation mosaic **Environmental Indicators** access and availability of economic, aesthetic, educational, and recreational resources; lifestyle and use trends; diversity of lifestyles; population and economic trends; scenic quality	**Affected by** Atmospheric Links all atmospheric elements Cultural/Social Links economic and political conditions; technology Hydrologic Links animal species, channel morphology, food web, hydrologic cycle, nutrient pathways, sediment, water Terrestrial Links animal species, erosion, fire, food web, genetic diversity, nutrient cycles, organic debris, plant species, soil hydrology, soil productivity, vegetation mosaic **Environmental Indicators** lifestyle and use trends; diversity of lifestyle; population and economic trends

Matrix of Key Ecosystem Elements - Cultural/Social Hierarchy

Ecosystem Element	Individual/ Small Group	Community/ Landscape	Subregion	Region
Social Organization **(Structure)**	**Description** family, household, small units tied by marriage, blood, and shared territory; communication **Relevance** <u>Cultural/Social Links</u> foundation of society, provides structure for behavior patterns at group level <u>Hydrologic Links</u> channel morphology <u>Terrestrial Links</u> animal species, erosion, fire, food web, plant species, vegetation mosaic	**Description** ordinances; club, church, youth groups, schools, businesses, networks, recreational groups, tribes; communication networks **Relevance** <u>Atmospheric Links</u> all atmospheric elements <u>Cultural/Social Links</u> structure for custom, tradition, and behavior at group level <u>Hydrologic Links</u> animal species, channel morphology, water <u>Terrestrial Links</u> animal species, erosion, fire, food web, genetic diversity, insects, nutrient cycles, organic debris, pathogens and diseases, plant species, soil hydrology, soil productivity, vegetation mosaic	**Description** ordinances and laws; city and county governments; service organizations; political groups; chambers of commerce; communication networks **Relevance** <u>Atmospheric Links</u> all atmospheric elements <u>Cultural/Social Links</u> facilitates interaction between large numbers of people; diversity of environment;, sharing common values; ensures adherence to laws; structure for custom, tradition, and behavior at group level <u>Hydrologic Links</u> animal species, channel morphology, food web, hydrologic cycle, nutrient pathways, organic debris, plant species, sediment, water <u>Terrestrial Links</u> animal species, erosion, fire, food web, genetic diversity, insects, nutrient cycles, organic debris, pathogens and diseases, plant species, soil hydrology, soil productivity, vegetation mosaic	**Description** laws and regulations; Constitution; state and national governments; regional organizations; national and international communications networks **Relevance** <u>Atmospheric Links</u> all atmospheric elements <u>Cultural/Social Links</u> facilitates interaction between large numbers of people; diversity of environment; sharing common values; ensures adherence to laws; structure for custom, tradition, and behavior at group level <u>Hydrologic Links</u> animal species, channel morphology, food web, hydrologic cycle, nutrient pathways, organic debris, plant species, sediment, water <u>Terrestrial Links</u> animal species, erosion, fire, food web, genetic diversity, insects, nutrient cycles, organic debris, pathogens and diseases, plant species, soil hydrology, soil productivity, vegetation mosaic

Matrix of Key Ecosystem Elements - Cultural/Social Hierarchy

Ecosystem Element	Individual/ Small Group	Community/ Landscape	Subregion	Region
Social Organization (continued)	**Affected by** <u>Cultural/Social Links</u> one-on-one communication; consensus of larger groups <u>Terrestrial Links</u> damage, fire, food web, plant species, soil hydrology, soil productivity, vegetation mosaic	**Affected by** <u>Atmospheric Links</u> all atmospheric elements <u>Cultural/Social Links</u> availability of services and resources; values and needs of people; communication and technology infrastructure; consensus of larger groups <u>Hydrologic Links</u> animal species, flooding, organic debris <u>Terrestrial Links</u> animal species, damage, fire, food web, genetic diversity, organic debris, plant species, soil hydrology, soil productivity, vegetation mosaic	**Affected by** <u>Atmospheric Links</u> all atmospheric elements <u>Cultural/Social Links</u> social and cultural trends; values and needs of people; education; laws; ideals; belief systems; attitudes; communication and technology infrastructure; consensus of larger groups <u>Hydrologic Links</u> animal species, channel morphology, flooding, food web, hydrologic cycle, nutrient pathways, organic debris, plant species, sediment, water <u>Terrestrial Links</u> animal species, damage, fire, food web, genetic diversity, organic debris, plant species, soil hydrology, soil productivity, vegetation mosaic	**Affected by** <u>Atmospheric Links</u> all atmospheric elements <u>Cultural/Social Links</u> social and cultural trends; values and needs of people; education; laws; ideals; belief systems; attitudes; communication and technology infrastructure; consensus of larger groups <u>Hydrologic Links</u> animal species, channel morphology, food web, hydrologic cycle, nutrient pathways, sediment, water <u>Terrestrial Links</u> animal species, damage, erosion, fire, food web, genetic diversity, organic debris, plant species, soil hydrology, soil productivity, vegetation mosaic

Matrix of Key Ecosystem Elements - Cultural/Social Hierarchy

Ecosystem Element	Individual/ Small Group	Community/ Landscape	Subregion	Region
Social Organization (continued)	**Environmental Indicators** group harmony; rate of change in membership, number, and complexity; effectiveness of communications	**Environmental Indicators** diversity of groups; compliance with rules, regulations, and laws; functional effectiveness; group harmony; rate of change in membership, number, and complexity; effectiveness of communications	**Environmental Indicators** diversity of groups; compliance with rules, regulations, and laws; functional effectiveness; group harmony; rate of change in membership, number, and complexity; effectiveness of communications	**Environmental Indicators** diversity of groups; compliance with rules, regulations, and laws; functional effectiveness; group harmony; rate of change in membership, number, and complexity; effectiveness of communications
Invention and Diffusion **(Process)**	**Description** individual creation, modification, and adoption of ideas; development of solutions and technology to meet personal needs or desires **Relevance** <u>Cultural/Social Links</u> key processes for cultural adaptation <u>Hydrologic Links</u> animal species, flooding, food web, hydrologic cycle, nutrient pathways, organic debris, plant species, water <u>Terrestrial Links</u> fire, food web, plant species, vegetation mosaic	**Description** community development of solutions and technology to meet community needs or desires **Relevance** <u>Atmospheric Links</u> all atmospheric elements <u>Cultural/Social Links</u> key processes for cultural adaptation; can observe subsistence pattern and social organizational changes at this scale <u>Hydrologic Links</u> all hydrologic elements	**Description** subregional development of solutions and technology to meet community needs or desires **Relevance** <u>Atmospheric Links</u> all atmospheric elements <u>Cultural/Social Links</u> key processes for cultural adaptation; can observe subsistence pattern and social organizational changes at this scale <u>Hydrologic Links</u> animal species, channel morphology, flooding, hydrologic cycle, nutrient pathways, organic debris, sediment, water	**Description** regional or global development of solutions and technology to meet community needs or desires **Relevance** <u>Atmospheric Links</u> all atmospheric elements <u>Cultural/Social Links</u> key processes for cultural adaptation; can observe subsistence pattern and social organizational changes at this scale <u>Hydrologic Links</u> animal species, channel morphology, flooding, hydrologic cycle, nutrient pathways, water

Matrix of Key Ecosystem Elements - Cultural/Social Hierarchy

Ecosystem Element	Individual/ Small Group	Community/ Landscape	Subregion	Region
Invention and Diffusion (continued)	**Affected by** Cultural/Social Links attitudes, beliefs, and values; technology; and resource availability Hydrologic Links animal species, channel morphology, food web, hydrologic cycle, nutrient pathways, organic debris, plant species, water Terrestrial Links animal species, damage, erosion, fire, food web, plant species, vegetation mosaic	**Affected by** Atmospheric Links all atmospheric elements Cultural/Social Links attitudes, beliefs, and values; technology; resource availability; social organization; transportation and communication structures Hydrologic Links all hydrologic elements Terrestrial Links all terrestrial elements Terrestrial Links animal species, fire, food web, genetic diversity, nutrient cycles, pathogens and diseases, plant species, vegetation mosaic	Terrestrial Links animal species, fire, food web, genetic diversity, nutrient cycles, pathogens and diseases, plant species, vegetation mosaic **Affected by** Atmospheric Links all atmospheric elements Cultural/Social Links attitudes, beliefs, and values; technology; resource availability; social organization; transportation and communication structures Hydrologic Links all hydrologic elements Terrestrial Links all terrestrial elements	Terrestrial Links animal species, fire, food web, genetic diversity, nutrient cycles, pathogens and diseases, plant species, vegetation mosaic **Affected by** Atmospheric Links all atmospheric elements Cultural/Social Links attitudes, beliefs, and values; technology; resource availability; social organization; transportation and communication structures Hydrologic Links animal species, channel morphology, food web, hydrologic cycle, nutrient pathways, sediment, water Terrestrial Links all terrestrial elements

Matrix of Key Ecosystem Elements - Cultural/Social Hierarchy

Ecosystem Element	Individual/ Small Group	Community/ Landscape	Subregion	Region
Invention and Diffusion (continued)	**Environmental Indicators** individual or household changes	**Environmental Indicators** rates and extent of cultural change; appearance of cultural traits; stylistic changes; complexity and types of material culture; changes in resource use	**Environmental Indicators** rates and extent of cultural change; appearance of cultural traits; stylistic changes; complexity and types of material culture; changes in resource use	**Environmental Indicators** rates and extent of cultural change; appearance of cultural traits; stylistic changes; complexity and types of material culture; changes in resource use
Land Use and Settlement Patterns **(Structure)**	**Description** households, work area, residential area **Relevance** <u>Terrestrial Links</u> animal species, damage, fire, food web, insects, plant species, soil hydrology, soil productivity, vegetation mosaic	**Description** sites, communities, neighborhoods, districts, countrysides **Relevance** <u>Atmospheric Links</u> all atmospheric elements <u>Cultural/Social Links</u> social organization; economics and subsistence <u>Hydrologic Links</u> animal species, flooding <u>Terrestrial Links</u> all terrestrial elements	**Description** cities, counties, drainages **Relevance** <u>Atmospheric Links</u> all atmospheric elements <u>Cultural/Social Links</u> social organization; economics and subsistence <u>Hydrologic Links</u> animal species, channel morphology, food web, hydrologic cycle, nutrient pathways, organic debris, plant species, sediment, water <u>Terrestrial Links</u> all terrestrial elements	**Description** regions, counties, states, provinces **Relevance** <u>Atmospheric Links</u> all atmospheric elements <u>Cultural/Social Links</u> social organization; economics and subsistence <u>Hydrologic Links</u> animal species, channel morphology, food web, hydrologic cycle, nutrient pathways, organic debris, sediment, water <u>Terrestrial Links</u> all terrestrial elements

Matrix of Key Ecosystem Elements - Cultural/Social Hierarchy

Ecosystem Element	Individual/ Small Group	Community/ Landscape	Subregion	Region
Land Use and Settlement Patterns (continued)	**Affected by** Cultural/Social Links other households, etc.; environmental constraints and opportunities Terrestrial Links animal species, fire, food web, insects, nutrient cycles, plant species, soil hydrology, soil productivity, vegetation mosaic **Environmental Indicators** presence of uses and infrastructure; numbers of houses, etc.; numbers of living/use surfaces; abundance; time; depth; activity spaces	**Affected by** Atmospheric Links all atmospheric elements Cultural/Social Links physical environment; population levels; resource distribution; technology; economic and political conditions Hydrologic Links animal species, flooding Terrestrial Links animal species, fire, food web, genetic diversity, insects, nutrient cycles, organic debris, pathogens and diseases, plant species, soil hydrology, soil productivity, vegetation mosaic **Environmental Indicators** presence of uses and infrastructure; abundance; community diversity; site complexity; district complexity; time; depth	**Affected by** Atmospheric Links all atmospheric elements Cultural/Social Links physical environment; population levels; resource distribution; technology; economic and political conditions Hydrologic Links all hydrologic elements Terrestrial Links animal species, fire, food web, genetic diversity, insects, nutrient cycles, organic debris, pathogens and diseases, plant species, soil hydrology, soil productivity, vegetation mosaic **Environmental Indicators** presence, diversity, and mix of uses and infrastructure; diversity; complexity; time; depth	**Affected by** Atmospheric Links all atmospheric elements Cultural/Social Links physical environment; population levels; resource distribution; technology; economic and political conditions Hydrologic Links animal species, channel morphology, food web, hydrologic cycle, nutrient pathways, sediment, water Terrestrial Links animal species, fire, food web, genetic diversity, insects, nutrient cycles, organic debris, pathogens and diseases, plant species, soil hydrology, soil productivity, vegetation mosaic **Environmental Indicators** presence, diversity, and mix of uses and infrastructure; diversity; complexity; time; depth

Matrix of Key Ecosystem Elements - Cultural/Social Hierarchy

Ecosystem Element	Individual/ Small Group	Community/ Landscape	Subregion	Region
Population Characteristics **(Structure)**	**Description** generally uniform, small in number, least complex, households, nuclear families, subsistence groups **Relevance** <u>Cultural/Social Links</u> immediate determinant for gathering subsistence cycles at the household level <u>Terrestrial Links</u> animal species, fire, food web, plant species, vegetation mosaic	**Description** some diversity, limited number, limited distribution, limited complexity **Relevance** <u>Atmospheric Links</u> nitrogen oxides, ozone, particulates <u>Cultural/Social Links</u> immediate determinant of demand on resources and ecosystems <u>Hydrologic Links</u> animal species, channel morphology, food web, hydrologic cycle, nutrient pathways, organic debris, plant species, water <u>Terrestrial Links</u> animal species, fire, food web, genetic diversity, nutrient cycles, organic debris, pathogens and diseases, plant species, soil hydrology, soil productivity, vegetation mosaic	**Description** highly diverse, greatest number, broad distribution, greatest complexity **Relevance** <u>Atmospheric Links</u> nitrogen oxides, ozone, sulfur compounds <u>Cultural/Social Links</u> variable determinant of demand on resources and ecosystems <u>Hydrologic Links</u> animal species, channel morphology, food web, hydrologic cycle, nutrient pathways, plant species, sediment, water <u>Terrestrial Links</u> animal species, fire, food web, genetic diversity, nutrient cycles, organic debris, pathogens and diseases, plant species, soil hydrology, soil productivity, vegetation mosaic	**Description** diverse, increased number, greater distribution, complex **Relevance** <u>Atmospheric Links</u> ozone, sulfur compounds <u>Cultural/Social Links</u> variable determinant of demand on resources and ecosystems <u>Hydrologic Links</u> channel morphology, food web, hydrologic cycle, nutrient pathways, water <u>Terrestrial Links</u> animal species, fire, food web, genetic diversity, nutrient cycles, organic debris, pathogens and diseases, plant species, soil hydrology, soil productivity, vegetation mosaic

Matrix of Key Ecosystem Elements - Cultural/Social Hierarchy

Ecosystem Element	Individual/ Small Group	Community/ Landscape	Subregion	Region
Population Characteristics (continued)	**Affected by** Cultural/Social Links subsistence technology; environmental constraints and opportunities; economics; education Terrestrial Links fire, food web, nutrient cycles, plant species, soil hydrology, soil productivity, vegetation mosaic	**Affected by** Atmospheric Links sulfur compounds Cultural/Social Links economics, education, migration, environmental constraints and opportunities Hydrologic Links animal species, flooding, food web, hydrologic cycle, nutrient pathways, plant species, sediment, water Terrestrial Links fire, food web, genetic diversity, nutrient cycles, pathogens and diseases, plant species, soil hydrology, soil productivity, vegetation mosaic	**Affected by** Atmospheric Links sulfur compounds Cultural/Social Links economics, environmental condition, education, migration Hydrologic Links animal species, flooding, food web, hydrologic cycle, nutrient pathways, plant species, sediment, water Terrestrial Links fire, food web, genetic diversity, nutrient cycles, pathogens and diseases, plant species, soil hydrology, soil productivity, vegetation mosaic	**Affected by** Atmospheric Links sulfur compounds Cultural/Social Links economics, environmental condition, education, migration Hydrologic Links animal species, hydrologic cycle, nutrient pathways, water Terrestrial Links fire, food web, genetic diversity, nutrient cycles, pathogens and diseases, plant species, soil hydrology, soil productivity, vegetation mosaic
	Environmental Indicators numbers of individuals; age; race/ethnic group; gender	**Environmental Indicators** size and distribution; balance between births and deaths; morbidity or incidence of disease; rate of reproduction; density; migration; age; race; gender; demographics	**Environmental Indicators** size and distribution; balance between births and deaths; morbidity or incidence of disease; rate of reproduction; density; migration; age; race; gender; complexity; demographics	**Environmental Indicators** size and distribution; balance between births and deaths; morbidity or incidence of disease; rate of reproduction; density; migration; age; race; gender; complexity; demographics

Matrix of Key Ecosystem Elements - Cultural/Social Hierarchy

Ecosystem Element	Individual/ Small Group	Community/ Landscape	Subregion	Region
Economics and Subsistence **(Process)**	**Description** income, gainful employment, food, clothing, shelter **Relevance** <u>Cultural/Social Links</u> survival, species reproduction, supports individuals (meets human needs) <u>Hydrologic Links</u> animal species, channel morphology, food web, hydrologic cycle, nutrient pathways, organic debris, sediment, water <u>Terrestrial Links</u> animal species, erosion, fire, food web, nutrient cycles, organic debris, plant species, soil hydrology, soil productivity, vegetation mosaic	**Description** goods and services; employment, skills and technology **Relevance** <u>Atmospheric Links</u> nitrogen oxides, ozone, particulates <u>Cultural/Social Links</u> supports communities; supports all "elements" <u>Hydrologic Links</u> all hydrologic elements <u>Terrestrial Links</u> animal species, erosion, fire, food web, genetic diversity, nutrient cycles, organic debris, pathogens and diseases, plant species, soil hydrology, soil productivity, vegetation mosaic	**Description** goods and services; employment; trade; technology; economic trends **Relevance** <u>Atmospheric Links</u> nitrogen oxides, ozone, particulates <u>Cultural/Social Links</u> supports subregions, counties, and states <u>Hydrologic Links</u> all hydrologic elements <u>Terrestrial Links</u> animal species, erosion, fire, food web, genetic diversity, nutrient cycles, organic debris, pathogens and diseases, plant species, soil hydrology, soil productivity, vegetation mosaic	**Description** trade, economic trends, technology **Relevance** <u>Atmospheric Links</u> nitrogen oxides, ozone, particulates <u>Cultural/Social Links</u> supports regions, states, and nations <u>Hydrologic Links</u> animal species, channel morphology, food web, hydrologic cycle, nutrient pathways, plant species, water <u>Terrestrial Links</u> animal species, erosion, fire, food web, genetic diversity, nutrient cycles, organic debris, pathogens and diseases, plant species, soil hydrology, soil productivity, vegetation mosaic

Matrix of Key Ecosystem Elements - Cultural/Social Hierarchy

Ecosystem Element	Individual/ Small Group	Community/ Landscape	Subregion	Region
Economics and Subsistence (continued)	**Affected by** Cultural/Social Links environmental, political and social constraints/opportunities Hydrologic Links animal species, flooding, food web, plant species, sediment, water Terrestrial Links animal species, damage, fire, food web, insects, nutrient cycles, plant species, soil hydrology, soil productivity, vegetation mosaic **Environmental Indicators** resource uses; budget; amount and distribution of income and employment; adequacy of food, clothing, and shelter	**Affected by** Atmospheric Links nitrogen oxides, ozone, particulates Cultural/Social Links technology; pollution; attitudes and skills; resource availability; (market conditions); natural and regional economy; invention Hydrologic Links all hydrologic elements Terrestrial Links all terrestrial elements **Environmental Indicators** resource uses, budget, employment rates, income levels per capita, tax revenues, rates of production/sales, housing availability, sales diversification, subsistence trends	**Affected by** Atmospheric Links nitrogen oxides, ozone, particulates Cultural/Social Links trade/economics; environmental constraints; invention Hydrologic Links all hydrologic elements Terrestrial Links all terrestrial elements **Environmental Indicators** resource uses, budget, employment trends, income levels per capita, tax revenues, rates of production/sales, housing availability, sales diversification, subsistence trends	**Affected by** Atmospheric Links nitrogen oxides, ozone, particulates Cultural/Social Links market condition; environmental constraints; invention Hydrologic Links animal species, channel morphology, flooding, food web, hydrologic cycle, nutrient pathways, water Terrestrial Links all terrestrial elements **Environmental Indicators** resource uses; budget; employment and economic trends; economic statistics

Matrix of Key Ecosystem Elements - Cultural/Social Hierarchy

Ecosystem Element	Individual/ Small Group	Community/ Landscape	Subregion	Region
Material Culture **(Component & Structure)**	**Description** artifacts, including tools, personal, and ceremonial objects, hybrids, domesticates, etc.; residential, commercial, recreational, and religious structures and buildings **Relevance** <u>Cultural/Social Links</u> physical evidence of human behavior <u>Hydrologic Links</u> animal species, channel morphology, food web, hydrologic cycle, organic debris, plant species, water <u>Terrestrial Links</u> animal species, damage, fire, food web, plant species, vegetation mosaic	**Description** residential, commercial, recreational, and religious complexes and cultural landscapes and their associated infrastructure **Relevance** <u>Atmospheric Links</u> all atmospheric elements <u>Cultural/Social Links</u> physical evidence of community behavior and relationships within the community to the environment <u>Hydrologic Links</u> animal species, channel morphology, flooding, food web, hydrologic cycle, nutrient pathways, organic debris, plant species, water <u>Terrestrial Links</u> animal species, damage, fire, food web, genetic diversity, plant species, vegetation mosaic	**Description** intercommunity complexes and landscapes at the city, county, tribal, or other subregional level **Relevance** <u>Atmospheric Links</u> all atmospheric elements <u>Cultural/Social Links</u> physical evidence of subregional behavior and relationships within the city, county, tribe, or other subregion <u>Hydrologic Links</u> animal species, channel morphology, flooding, hydrologic cycle, nutrient pathways, water <u>Terrestrial Links</u> animal species, damage, fire, food web, genetic diversity, plant species, vegetation mosaic	**Description** broader statewide, province, and national level complexes and cultural landscapes, and their associated infrastructure **Relevance** <u>Atmospheric Links</u> all atmospheric elements <u>Cultural/Social Links</u> physical evidence of regional behavior and relationships within the state, province, or nation <u>Hydrologic Links</u> channel morphology, flooding, hydrologic cycle, nutrient pathways, water <u>Terrestrial Links</u> animal species, damage, fire, food web, genetic diversity, plant species, vegetation mosaic

Matrix of Key Ecosystem Elements - Cultural/Social Hierarchy

Ecosystem Element	Individual/ Small Group	Community/ Landscape	Subregion	Region
Material Culture (continued)	**Affected by** Cultural/Social Links available resources, learned behavior, needs and desires, and invention Hydrologic Links animal species, channel morphology, food web, nutrient pathways, organic debris, sediment, water Terrestrial Links animal species, damage, erosion, fire, food web, plant species, vegetation mosaic **Environmental Indicators** numbers and types of artifacts, objects, features, structures, etc.	**Affected by** Atmospheric Links all atmospheric elements Cultural/Social Links available resources, learned behavior, needs and desires, and invention Hydrologic Links animal species, channel morphology, flooding, food web, hydrologic cycle, nutrient pathways, organic debris, sediment, water Terrestrial Links animal species, damage, erosion, fire, food web, genetic diversity, nutrient cycles, organic debris, pathogens and diseases, plant species, soil hydrology **Environmental Indicators** numbers or diversity and complexity of types of artifacts, objects, features, structures, etc.	**Affected by** Atmospheric Links all atmospheric elements Cultural/Social Links available resources, learned behavior, needs and desires, and invention Hydrologic Links animal species, channel morphology, food web, hydrologic cycle, nutrient pathways, sediment, water Terrestrial Links animal species, damage, erosion, fire, food web, genetic diversity, nutrient cycles, organic debris, pathogens and diseases, plant species, soil hydrology, vegetation mosaic **Environmental Indicators** numbers and increasing diversity and complexity of artifacts, objects, features, structures, etc.	**Affected by** Atmospheric Links all atmospheric elements Cultural/Social Links available resources; learned behavior; needs and desires; and invention Hydrologic Links animal species, channel morphology, food web, hydrologic cycle, nutrient pathways, sediment, water Terrestrial Links animal species, damage, erosion, fire, food web, genetic diversity, nutrient cycles, organic debris, pathogens and diseases, plant species, soil hydrology, vegetation mosaic **Environmental Indicators** numbers and increasing diversity and complexity of artifacts, objects, features, structures, etc.

Matrix of Hydrologic Ecosystem Elements - Hydrologic Hierarchy

Ecosystem Element	Site (No order)	Subwatershed (1-3 order)	Watershed (3-5 order)	River Basin (5-7 order)	Icthyological Province
Animal Species **(Component)**	**Description** occurrence, diversity, health **Relevance** <u>Cultural/Social Links</u> attitudes, beliefs, and values; lifestyles and lifeways; economics and subsistence; material culture; invention <u>Hydrologic Links</u> nutrient pathways; other animal species (predation, competition, mutualism); aquatic plant species; organic debris <u>Terrestrial Links</u> animal species	**Description** species distribution and abundance; community structure; plant associations; guilds **Relevance** <u>Cultural/Social Links</u> attitudes, beliefs, and values; lifestyles and lifeways; land use and settlement patterns; social organization; economics and subsistence; material culture; invention and diffusion <u>Hydrologic Links</u> nutrient pathways; other animal species (predation , competition, mutualism); aquatic plant species; organic debris <u>Terrestrial Links</u> animal species	**Description** faunal assemblages, community structure, plant associations, guilds **Relevance** <u>Cultural/Social Links</u> all cultural/social elements <u>Hydrologic Links</u> nutrient pathways; other animal species (predation , competition, mutualism); aquatic plant species; organic debris <u>Terrestrial Links</u> animal species	**Description** genetic diversity, meta-populations, ecotones, migrations, population viability, resilience, stability **Relevance** <u>Cultural/Social Links</u> attitudes, beliefs, and values; lifestyles and lifeways; land use and settlement patterns; social organization; population characteristics; economics and subsistence; material culture; diffusion <u>Hydrologic Links</u> other animal species (predation , competition, mutualism); aquatic plant species; organic debris <u>Terrestrial Links</u> animal species	**Description** genetic diversity **Relevance** <u>Cultural/Social Links</u> attitudes, beliefs, and values; lifestyles and lifeways; social organization; population characteristics; economics and subsistence; diffusion <u>Hydrologic Links</u> other animal species (predation , competition, mutualism); aquatic plant species; organic debris <u>Terrestrial Links</u> animal species

Matrix of Hydrologic Ecosystem Elements - Hydrologic Hierarchy

Ecosystem Element	Site (No order)	Subwatershed (1-3 order)	Watershed (3-5 order)	River Basin (5-7 order)	Icthyological Province
Animal Species (continued)	**Affected by** Cultural/Social Links attitudes, beliefs, and values; lifestyles and lifeways; economics and subsistence; material culture; invention Hydrologic Links presence or absence of habitat; other animal species Terrestrial Links animal species **Environmental Indicators** counts, diversity indices, necropsy, growth and reproduction fecundity	**Affected by** Cultural/Social Links all cultural/social elements Hydrologic Links habitat distribution and abundance; flood; erosion Terrestrial Links animal species, fire **Environmental Indicators** census, ecoclassification, population estimates, diversity indices	**Affected by** Cultural/Social Links all cultural/social elements Hydrologic Links habitat distribution and abundance; flood; erosion Terrestrial Links animal species, fire **Environmental Indicators** census, ecoclassification, life stables, food web analyses	**Affected by** Cultural/Social Links all cultural/social elements Hydrologic Links habitat distribution and abundance; flood; erosion Terrestrial Links animal species, fire **Environmental Indicators** census, ecoclassification, radio- telemetry, tracking, mark and recapture	**Affected by** Cultural/Social Links attitudes, beliefs, and values; lifestyles and lifeways; social organization; economics and subsistence; material culture; invention and diffusion Hydrologic Links habitat distribution and abundance **Environmental Indicators** census, ecoclassification, radio- telemetry, tracking, mark and recapture

Matrix of Hydrologic Ecosystem Elements - Hydrologic Hierarchy

Ecosystem Element	**Site (No order)**	**Subwatershed (1-3 order)**	**Watershed (3-5 order)**	**River Basin (5-7 order)**	**Icthyological Province**
Channel Morphology **(Component & Structure)**	**Description** pools, riffles, runs, undercut banks, gravel bars **Relevance** Cultural/Social Links material culture Hydrologic Links channel unit complexity (shape, depth, cover) **Affected by** Atmospheric Links climate Cultural/Social Links attitudes, beliefs, and values; lifeways and lifeways; social	**Description** meanders, gradient, confinement, flood plains, mix of channel units **Relevance** Cultural/Social Links attitudes, beliefs, and values; lifestyles and lifeways; economics and subsistence; material culture; invention and diffusion Hydrologic Links habitat diversity, channel stability **Affected by** Atmospheric Links climate Cultural/Social Links attitudes, beliefs, and values; lifeways and lifeways; social	**Description** sinuosity, stream confluences, depositional features, flood plains, topography, valley reaches **Relevance** Cultural/Social Links attitudes, beliefs, and values; lifestyles and lifeways; land use and settlement patterns; social organization; economics and subsistence; material culture; invention and diffusion Hydrologic Links habitat diversity, channel stability, microclimates **Affected by** Atmospheric Links climate Cultural/Social Links all cultural/social elements	**Description** geomorphic features, drainage density and pattern, sinuosity, deltas, topography **Relevance** Cultural/Social Links attitudes, beliefs and values; lifestyles and lifeways; land use settlement pattern; social organization; economics and subsistence; material culture; invention and diffusion Hydrologic Links habitat abundance and diversity; geomorphic processes (i.e., sediment routing) **Affected by** Atmospheric Links climate Cultural/Social Links all cultural/social elements	**Description** drainage density **Relevance** Cultural/Social Links attitudes, beliefs and values; lifestyles and lifeways; land use settlement pattern; social organization; economics and subsistence; material culture; invention and diffusion Hydrologic Links flow Terrestrial Links geomorphic processes **Affected by** Atmospheric Links climate Cultural/Social Links all cultural/social elements

Matrix of Hydrologic Ecosystem Elements - Hydrologic Hierarchy

Ecosystem Element	Site (No order)	Subwatershed (1-3 order)	Watershed (3-5 order)	River Basin (5-7 order)	Icthyological Province
Channel Morphology (continued)	Cultural/Social Links (continued) organization; economics and subsistence; material culture; invention and diffusion Hydrologic Links substrate, organic debris, water velocity, flow Terrestrial Links geology **Environmental Indicators** gradient; width; volume; depth of pools, riffles, and runs; gravel bars; bank steepness	Cultural/Social Links (continued) organization; population characteristics; economics and subsistence; material culture; invention and diffusion Hydrologic Links substrate, organic debris, riparian vegetation, discharge Terrestrial Links geology, upslope vegetation **Environmental Indicators** sinuosity, confinement, andgradient (Rosgen Channel Types); pool/riffle ratios; width/depth ratio; bank stability; habitat inventory	Hydrologic Links flow Terrestrial Links geology, geomorphic processes, topography **Environmental Indicators** sinuosity, confinement, and gradient (Rosgen Channel Types); pool/riffle ratios; landslide occurrence; habitat inventory	Hydrologic Links flow Terrestrial Links geology, geomorphic processes **Environmental Indicators** sinuosity, confinement, and gradient (Rosgen Channel Types); mass movement occurrence and distribution; miles of stream per area; topography	Hydrologic Links flow Terrestrial Links geology, geomorphic processes **Environmental Indicators** miles of stream per area

Matrix of Hydrologic Ecosystem Elements - Hydrologic Hierarchy

Ecosystem Element	Site (No order)	Subwatershed (1-3 order)	Watershed (3-5 order)	River Basin (5-7 order)	Icthyological Province
Erosion **(Process)**	**Description** slumps, gully, landslide, sedimentation, scour **Relevance** Hydrologic Links bank stability, channel morphology, habitat, riparian plants **Affected by** Cultural/Social Links lifestyles and lifeways; social organization; economics and subsistence; material culture; invention Hydrologic Links flooding Terrestrial Links geology, fire	**Description** gully; mass movements and failures; depositional features; sedimentation; scour **Relevance** Cultural/Social Links lifestyles and lifeways; economics and subsistence Hydrologic Links bank stability, channel features, channel morphology, riparian plants, water quality (turbidity) **Affected by** Cultural/Social Links lifestyles and lifeways; land use and settlement patterns; social organization; economics and subsistence; material culture; invention and diffusion Hydrologic Links flooding	**Description** mass movements and failures; depositional features; sedimentation; scour **Relevance** Cultural/Social Links lifestyles and lifeways; economics and subsistence Hydrologic Links animal species, channel features, channel morphology, riparian plants, water quality (turbidity) **Affected by** Cultural/Social Links lifestyles and lifeways; land use and settlement patterns; social organization; economics and subsistence; material culture; invention and diffusion Hydrologic Links flooding	**Description** mass movements and failures; depositional features; sedimentation **Relevance** Cultural/Social Links lifestyles and lifeways; social organization; economics and subsistence Hydrologic Links animal species, channel morphology, water quality (turbidity, temperature) **Affected by** Cultural/Social Links lifestyles and lifeways; land use and settlement patterns; social organization; economics and subsistence; diffusion Hydrologic Links flooding Terrestrial Links geology, fire	**Description** N/A **Relevance** N/A **Affected by** N/A

Matrix of Hydrologic Ecosystem Elements - Hydrologic Hierarchy

Ecosystem Element	Site (No order)	Subwatershed (1-3 order)	Watershed (3-5 order)	River Basin (5-7 order)	Icthyological Province
Erosion (continued)	**Environmental Indicators** presence and absence	<u>Terrestrial Links</u> geology, fire **Environmental Indicators** volume, areal extent, frequency	<u>Terrestrial Links</u> geology, fire **Environmental Indicators** volume, areal extent, frequency, distribution, sediment budget	**Environmental Indicators** at frequency, distribution, volume, sediment budget	**Environmental Indicators** N/A
Fire **(Process)**	**Description** combustion of organic material and nutrients **Relevance** <u>Atmospheric Links</u> particulates <u>Hydrologic Links</u> habitats, animal species, plant species, erosion <u>Terrestrial Links</u> infiltration rates, nutrient release, vegetation mosaic	**Description** combustion of organic material and nutrients **Relevance** <u>Atmospheric Links</u> particulates <u>Hydrologic Links</u> stream temperature; habitat composition and structure (i.e., shade, canopy, woody debris availability); surface erosion rates <u>Terrestrial Links</u> infiltration rates, nutrient release, vegetation mosaic	**Description** combustion of organic material and nutrients **Relevance** <u>Atmospheric Links</u> particulates <u>Hydrologic Links</u> habitat composition and structure (i.e., shade, canopy, woody debris availability); nutrient release; surface erosion rates <u>Terrestrial Links</u> infiltration rates, nutrient release, vegetation mosaic	**Description** combustion of organic material and nutrients **Relevance** <u>Atmospheric Links</u> particulates <u>Hydrologic Links</u> habitat composition and structure (i.e., shade, canopy, woody debris availability); surface erosion rates <u>Terrestrial Links</u> infiltration rates, nutrient release, vegetation mosaic	**Description** combustion of organic material and nutrients **Relevance** <u>Hydrologic Links</u> animal and plant populations <u>Terrestrial Links</u> animal and plant populations

Matrix of Hydrologic Ecosystem Elements - Hydrologic Hierarchy

Ecosystem Element	Site (No order)	Subwatershed (1-3 order)	Watershed (3-5 order)	River Basin (5-7 order)	Icthyological Province
Fire (continued)	**Affected by** Atmospheric Links climate Hydrologic Links riparian vegetation Terrestrial Links fuel loads, plant species, topography, aspect **Environmental Indicators** intensity, duration, and magnitude: severity, size, distribution (location in the landscape)	**Affected by** Atmospheric Links climate Hydrologic Links riparian vegetation Terrestrial Links fuel loads, plant species, topography, aspect **Environmental Indicators** intensity, duration, and magnitude: severity, size, distribution (location in the landscape, return rate, seasonality	**Affected by** Atmospheric Links climate Hydrologic Links riparian vegetation Terrestrial Links fuel loads, plant species, topography, aspect **Environmental Indicators** intensity, duration, and magnitude: severity, size, distribution (location in the landscape, return rate, seasonality	**Affected by** Atmospheric Links climate Hydrologic Links riparian vegetation Terrestrial Links fuel loads, plant species, topography, aspect **Environmental Indicators** intensity, duration, and magnitude: severity, size, distribution (location in the landscape, return rate, seasonality	**Affected by** Atmospheric Links climate Hydrologic Links riparian vegetation Terrestrial Links fuel loads, plant species, topography, aspect **Environmental Indicators** intensity, duration, and magnitude: severity, size, distribution (location in the landscape, return rate, seasonality

Matrix of Hydrologic Ecosystem Element - Hydrologic Hierarchy

Ecosystem Element	Site (No order)	Subwatershed (1-3 order)	Watershed (3-5 order)	River Basin (5-7 order)	Icthyological Province
Flooding **(Process)**	**Description** flow exceeds bankfull causing bedload movement, sedimentation, and channel alterations **Relevance** <u>Cultural/Social Links</u> attitudes, beliefs, and values; lifestyles and lifeways; economics and subsistence; invention <u>Hydrologic Links</u> habitat, animal and plant species, substrate, erosion, channel morphology <u>Terrestrial Links</u> plant species, organic debris **Affected by** <u>Atmospheric Links</u> climate <u>Cultural/Social Links</u> attitudes, beliefs, and values	**Description** flow exceeds bankfull causing bedload movement, sedimentation, and channel alterations **Relevance** <u>Cultural/Social Links</u> all cultural/social elements <u>Hydrologic Links</u> habitat, animal species, plant species, erosion, channel morphology <u>Terrestrial Links</u> plant species, organic debris **Affected by** <u>Atmospheric Links</u> climate <u>Cultural/Social Links</u> attitudes, beliefs, and values; land use and settlement patterns;	**Description** flow exceeds bankfull causing bedload movement, sedimentation, and channel alterations **Relevance** <u>Cultural/Social Links</u> all cultural/social elements <u>Hydrologic Links</u> habitat, animal species, plant species, erosion, channel morphology <u>Terrestrial Links</u> animal and plant species **Affected by** <u>Atmospheric Links</u> climate <u>Cultural/Social Links</u> attitudes, beliefs, and values; land use and settlement patterns;	**Description** flow exceeds bankfull causing bedload movement, sedimentation, and channel alterations **Relevance** <u>Cultural/Social Links</u> all cultural/social elements <u>Hydrologic Links</u> habitat, animal species, plant species, erosion, channel morphology <u>Terrestrial Links</u> animal and plant species **Affected by** <u>Atmospheric Links</u> climate <u>Cultural/Social Links</u> diffusion <u>Terrestrial Links</u> geology	**Description** flow exceeds bankfull causing bedload movement, sedimentation, and channel alterations **Relevance** <u>Cultural/Social Links</u> diffusion <u>Hydrologic Links</u> animal species, plant species, channel morphology <u>Terrestrial Links</u> animal and plant species **Affected by** <u>Atmospheric Links</u> climate <u>Terrestrial Links</u> geology

Matrix of Hydrologic Ecosystem Elements - Hydrologic Hierarchy

Ecosystem Element	Site (No order)	Subwatershed (1-3 order)	Watershed (3-5 order)	River Basin (5-7 order)	Icthyological Province
Flooding (continued)	Hydrologic Links channel morphology Terrestrial Links geology	Cultural/Social Links (continued) economics and subsistence; material culture; invention	Cultural/Social Links (continued) economics and subsistence; material culture; invention and diffusion Hydrologic Links channel morphology, drainage density and pattern		
	Environmental Indicators magnitude, intensity, duration, recurrence interval, discharge, peak flow indicators (leaf scour, debris deposits), flood plain changes, damage to riparian zone, secondary channel flow	**Environmental Indicators** magnitude, intensity, duration, recurrence interval, discharge, peak flow indicators (leaf scour, debris deposits), flood plain changes, damage to riparian zone, secondary channel flow	**Environmental Indicators** magnitude, intensity, duration, recurrence interval, discharge, flood plain changes, damage to riparian zone, secondary channel flow	**Environmental Indicators** magnitude, intensity, duration, recurrence interval, discharge	**Environmental Indicators** magnitude, intensity, duration, recurrence interval, discharge

Matrix of Hydrologic Ecosystem Elements - Hydrologic Hierarchy

Ecosystem Element	Site (No order)	Subwatershed (1-3 order)	Watershed (3-5 order)	River Basin (5-7 order)	Icthyological Province
Food Web **(Component & Structure)**	**Description** network of organisms making up the biotic component of a nutrient pathway **Relevance** <u>Cultural/Social Links</u> lifestyles and lifeways; economics and subsis-tence; material culture; invention <u>Hydrologic Links</u> animal and plant species (predator/prey relation-ships); nutrient pathways <u>Terrestrial Links</u> animal species, food web **Affected by** <u>Cultural/Social Links</u> lifestyles and lifeways; economics and subsis-tence; material culture; invention	**Description** network of organisms making up the biotic component of a nutrient pathway **Relevance** <u>Cultural/Social Links</u> lifestyles and lifeways; population character-istics; economics and subsistence; material culture; invention <u>Hydrologic Links</u> animal and plant species (predator/prey relation-ships); nutrient pathways <u>Terrestrial Links</u> animal species, food web **Affected by** <u>Cultural/Social Links</u> lifestyles and lifeways; population characteri-stics; economics and subsistence; material culture; invention and diffusion	**Description** network of organisms making up the biotic component of a nutrient pathway **Relevance** <u>Cultural/Social Links</u> lifestyles and lifeways; land use and settlement patterns; social organiza-tion; population character-istics; economics and subsistence; material culture; invention and diffusion <u>Hydrologic Links</u> animal and plant species (predator/prey relation-ships); nutrient pathways <u>Terrestrial Links</u> animal species, food web **Affected by** <u>Cultural/Social Links</u> lifestyles and lifeways; land use and settlement patterns; social organization; population characteristics; economics	**Description** network of organisms making up the biotic component of a nutrient pathway **Relevance** <u>Cultural/Social Links</u> lifestyles and lifeways; land use and settlement patterns; social organiza-tion; population character-istics; economics and subsistence <u>Hydrologic Links</u> animal and plant species (predator/prey relation-ships); nutrient pathways <u>Terrestrial Links</u> animal species, food web **Affected by** <u>Cultural/Social Links</u> lifestyles and lifeways; land use and settlement patterns; social organization; population characteristics; economics	**Description** network of organisms making up the biotic component of a nutrient pathway **Relevance** <u>Cultural/Social Links</u> lifestyles and lifeways social organization; economics and subsistence <u>Hydrologic Links</u> animal and plant species (predator/prey relation-ships); nutrient pathways <u>Terrestrial Links</u> animal species, food web **Affected by** <u>Cultural/Social Links</u> attitudes, beliefs, and values; lifestyles and lifeways; social organization; population

Matrix of Hydrologic Ecosystem Elements - Hydrologic Hierarchy

Ecosystem Element	Site (No order)	Subwatershed (1-3 order)	Watershed (3-5 order)	River Basin (5-7 order)	Icthyological Province
Food Web (continued)	Hydrologic Links flood, erosion, nutrient availability and exchange; animal and plant species (assemblages, population dynamics) Terrestrial Links animal species, fire, food web, nutrient cycles **Environmental Indicators** plankton and macroinvertebrate samples; community diversity indices (micro & macro); food availability, stability and resilience	Hydrologic Links flood, erosion, nutrient availability and exchange; animal and plant species (assemblages, population dynamics) Terrestrial Links animal species, fire, food web, nutrient cycles **Environmental Indicators** producer to predator ratios; species assemblages; community diversity indices (micro & macro); food availability, stability and resiliency	Cultural/Social Links (continued) and subsistence; material culture; diffusion Hydrologic Links flood, erosion, nutrient availability and exchange; animal and plant species (assemblages, population dynamics) Terrestrial Links animal species, fire, food web, nutrient cycles **Environmental Indicators** species assemblages; population stability and resiliency	Cultural/Social Links (continued) and subsistence; material culture; diffusion Hydrologic Links flood, erosion, nutrient availability and exchange; animal and plant species (assemblages, population dynamics) Terrestrial Links animal species, fire, food web, nutrient cycles **Environmental Indicators** species assemblages; population or community stability and resiliency	Cultural/Social Links (continued) characteristics; economics and subsistence; material culture; diffusion Hydrologic Links animal species (migration) **Environmental Indicators** species assemblages; community stability and resiliency

Matrix of Hydrologic Ecosystem Elements - Hydrologic Hierarchy

Ecosystem Element	**Site (No order)**	**Subwatershed (1-3 order)**	**Watershed (3-5 order)**	**River Basin (5-7 order)**	**Icthyological Province**
Hydrologic Cycle **(Process)**	**Description** precipitation and evapo-transpiration **Relevance** <u>Cultural/Social Links</u> attitudes, beliefs, and values; material culture; invention and diffusion <u>Hydrologic Links</u> channel morphology; substrate; nutrient cycles; water velocity and turbu-lence; animal and plant species <u>Terrestrial Links</u> nutrient cycle, animal and plant species **Affected by** <u>Atmospheric Links</u> climate	**Description** precipitation, evapotranspira-tion, runoff, sediment routing, groundwater **Relevance** <u>Cultural/Social Links</u> attitudes, beliefs, and values; lifestyles and lifeways; population characteristics; economics and subsistence; material culture; invention and diffusion <u>Hydrologic Links</u> nutrient cycle; discharge flow and timing; sediment routing; animal and plant species <u>Terrestrial Links</u> nutrient cycle; animal and plant species **Affected by** <u>Atmospheric Links</u> climate	**Description** precipitation, evapotranspira-tion, runoff, sediment routing, groundwater **Relevance** <u>Cultural/Social Links</u> all cultural/social elements <u>Hydrologic Links</u> nutrient cycle; discharge flow and timing; sediment routing; animal and plant species <u>Terrestrial Links</u> nutrient cycle; animal and plant species **Affected by** <u>Atmospheric Links</u> climate	**Description** precipitation, evapotranspira-tion, runoff, sediment routing, groundwater **Relevance** <u>Cultural/Social Links</u> all cultural/social elements <u>Hydrologic Links</u> nutrient cycle; discharge flow and timing; sediment routing; animal and plant species <u>Terrestrial Links</u> nutrient cycle; animal and plant species **Affected by** <u>Atmospheric Links</u> climate	**Description** precipitation, evapotrans-piration, runoff, sediment routing, groundwater **Relevance** <u>Cultural/Social Links</u> all cultural/social elements <u>Hydrologic Links</u> hydrologic regime; animal and plant species <u>Terrestrial Links</u> nutrient cycle; animal and plant species; geomorphic processes **Affected by** <u>Atmospheric Links</u> climate

Matrix of Hydrologic Ecosystem Elements - Hydrologic Hierarchy

Ecosystem Element	Site (No order)	Subwatershed (1-3 order)	Watershed (3-5 order)	River Basin (5-7 order)	Icthyological Province
Hydrologic Cycle (continued)	<u>Cultural/Social Links</u> economics and subsistence; material culture; invention <u>Hydrologic Links</u> flooding <u>Terrestrial Links</u> physiography (local elevation & aspect); plant species and vegetative mosaic (cover type and density) **Environmental Indicators** evapotranspiration rates; precipitation records; water table measures; water velocity, volume, and turbidity	<u>Cultural/Social Links</u> lifestyle and lifeways; population characteristics; economics and subsistence; material culture; invention <u>Hydrologic Links</u> flooding <u>Terrestrial Links</u> physiography (elevation); plant species and vegetative mosaic (cover type and density) **Environmental Indicators** discharge and volume; precipitation records; water budget; water table measures; turbidity	<u>Cultural/Social Links</u> all cultural/social elements <u>Hydrologic Links</u> flooding <u>Terrestrial Links</u> physiography (latitude and longitude); plant species and vegetative mosaic (cover type and density) **Environmental Indicators** discharge and volume; precipitation records; water budget	<u>Cultural/Social Links</u> all cultural/social elements <u>Hydrologic Links</u> flooding <u>Terrestrial Links</u> physiography (latitude and longitude); vegetative mosaic (cover type and density) **Environmental Indicators** discharge and volume; precipitation records; water budget; hydrographs	<u>Cultural/Social Links</u> all cultural/social elements <u>Hydrologic Links</u> flooding <u>Terrestrial Links</u> physiography (latitude and longitude); vegetative mosaic (cover type and density) **Environmental Indicators** annual precipitation hydrograph; annual hydrography; annual minimum, maximum, and base flows; regional aquifers

Matrix of Hydrologic Ecosystem Elements - Hydrologic Hierarchy

Ecosystem Element	Site (No order)	Subwatershed (1-3 order)	Watershed (3-5 order)	River Basin (5-7 order)	Icthyological Province
Nutrient Pathways **(Process)**	**Description** transfer and breakdown (mechanical and biological) of nutrients within and between terrestrial and aquatic systems **Relevance** Cultural/Social Links attitudes, beliefs, and values; invention Hydrologic Links animal and plant species (nutrient availability, photosyn-thesis); organic debris (allochthonous sources) Terrestrial Links animal and plant species (nutrient availability, photosyn-thesis); nutrient cycles; organic debris (allochthonous sources)	**Description** transfer, breakdown, and movement of nutrients within and between terrestrial and aquatic systems **Relevance** Cultural/Social Links attitudes, beliefs, and values; lifestyles and lifeways; economics and subsistence; invention Hydrologic Links animal and plant species (nutrient availability, photosynthesis, population dynamics); organic debris (allochthonous and autochthonous sources); sediment (pools, sink, source) Terrestrial Links animal and plant species (nutrient availability, photosynthesis, population dynamics); nutrient cycles (stability	**Description** transfer, breakdown, and movement of nutrients within and between terrestrial and aquatic systems **Relevance** Cultural/Social Links all cultural social elements Hydrologic Links animal and plant species (population dynamics, productivity); nutrient spiraling; organic debris (allochthonous and autochthonous sources); sediment (pools, sink, source) Terrestrial Links animal and plant species (population dynamics, productivity); nutrient cycles (stability and resiliency); nutrient spiraling; organic debris (alochthonous and autochthonous sources); soils	**Description** net balance of nutrients from their transfer, breakdown, and movement within and between terrestrial and aquatic systems **Relevance** Cultural/Social Links all cultural/social elements Hydrologic Links animal and plant species (population dynamics, productivity, fish migration, plant succession); nutrient spiraling; organic debris (allochthonous and autochthonous sources); sediment (pools, sink, source) Terrestrial Links animal and plant species (population dynamics, productivity); nutrient cycles (stability and resiliency); nutrient spiraling; organic debris (alochthonous and autochthonous sources); soils	**Description** net balance of nutrients from their transfer, breakdown, and movement within and between terrestrial and aquatic systems **Relevance** Cultural/Social Links all cultural/social elements Hydrologic Links animal and plant species (population dynamics, productivity, fish migration, plant succession); nutrient spiraling; organic debris (allochthonous and autochthonous sources); sediment (pools, sink, source) Terrestrial Links animal and plant species (population dynamics, productivity); nutrient cycles (stability and resiliency); nutrient spiraling; organic debris (alochthonous and autochthonous sources);

Matrix of Hydrologic Ecosystem Elements - Hydrologic Hierarchy

Ecosystem Element	Site (No order)	Subwatershed (1-3 order)	Watershed (3-5 order)	River Basin (5-7 order)	Icthyological Province
Nutrient Pathways (continued)		Terrestrial Links (continued) and resiliency); organic debris (alochthonous and autochthonous sources) soils (pools, sinks, sources)	Terrestrial Links (continued) (pools, sinks, sources, productivity)	Terrestrial Links (continued) (pools, sinks, sources, productivity); vegetation mosaic (longitudinal succession)	Terrestrial Links (continued) soils (pools, sinks, sources, productivity); vegetation mosaic (longitudinal succession)
	Affected by Cultural/Social Links attitudes, beliefs, and values; lifestyles and lifeways; economics and subsistence; material culture; invention Hydrologic Links animal species, floods, food web, organic debris, sediment, water budget Terrestrial Links erosion, fire, food web, nutrient cycles, organic debris, soils, windthrow and storm damage	**Affected by** Cultural/Social Links attitudes, beliefs, and values; lifestyles and lifeways; economics and subsistence; material culture; invention Hydrologic Links animal species, floods, food web, organic debris, sediment, water budget Terrestrial Links erosion, fire, food web, nutrient cycles, organic debris, soils, windthrow and storm damage	**Affected by** Atmospheric Links ozone, nitrogen oxides, sulfur dioxide Cultural/Social Links all cultural/social elements Hydrologic Links animal species, floods, food web, organic debris, sediment, water budget Terrestrial Links erosion, fire, food web, nutrient cycles, organic debris, soils	**Affected by** Atmospheric Links ozone, nitrogen oxides, sulfur dioxide Cultural/Social Links all cultural/social elements Hydrologic Links floods, organic debris, sediment, water budget Terrestrial Links erosion, fire, nutrient cycles, organic debris, soils	**Affected by** Atmospheric Links climate, ozone, nitrogen oxides, sulfur dioxide Cultural/Social Links all cultural/social elements Hydrologic Links water budget Terrestrial Links geology, nutrient cycles, topography

Matrix of Hydrologic Ecosystem Elements - Hydrologic Hierarchy

Ecosystem Element	**Site (No order)**	**Subwatershed (1-3 order)**	**Watershed (3-5 order)**	**River Basin (5-7 order)**	**Icthyological Province**
Nutrient Pathways (continued)	**Environmental Indicators** fish carcasses; detritus; woody debris; decay class; drift; benthos and plankton samples; bioenergetics and growth residence time (i.e., storage and exchange)	**Environmental Indicators** fish carcasses; detritus; primary and secondary production (i.e., biomass growth/time); food web analysis; bioenergetics and growth residence time (i.e.,. storage and exchange)	**Environmental Indicators** fish carcasses; detritus; primary and secondary production; food web analysis; bioenergetics and growth residence time (i.e., storage and exchange)	**Environmental Indicators** fish carcasses; detritus; primary and secondary production; downstream shifts in species assemblages; food web analysis; bioenergetics and growth residence time (i.e., storage & growth)	**Environmental Indicators** downstream shifts in species assemblages; food web analysis
Organic Debris **(Component & Structure)**	**Description** small and large woody debris (leaf litter, detritus, logs, and limbs) **Relevance** <u>Cultural/Social Links</u> attitudes, beliefs, and values; lifestyles and lifeways; material culture; invention	**Description** instream logs and log jams **Relevance** <u>Cultural/Social Links</u> attitudes, beliefs, and values; lifestyles and lifeways; social organization; economics and subsistence; material culture; invention	**Description** instream logs and log jams; riparian woody debris **Relevance** <u>Cultural/Social Links</u> attitudes, beliefs, and values; lifestyles and lifeways; land use and settlement patterns; social organization; economics and subsistence; material culture; invention and diffusion	**Description** instream large log jams, riparian woody debris deposits **Relevance** <u>Cultural/Social Links</u> economics and subsistence; invention and diffusion	**Description** N/A **Relevance** N/A

Matrix of Hydrologic Ecosystem Elements - Hydrologic Hierarchy

Ecosystem Element	Site (No order)	Subwatershed (1-3 order)	Watershed (3-5 order)	River Basin (5-7 order)	Icthyological Province
Organic Debris (continued)	<u>Hydrologic Links</u> microhabitat (spatial and temporal types, size, amount, distribution, and complexity); riparian vegetation; substrate sorting <u>Terrestrial Links</u> plant species **Affected by** <u>Cultural/Social Links</u> attitudes, beliefs, and values; lifestyles and lifeways; economics and subsistence; material culture; invention <u>Hydrologic Links</u> flooding <u>Terrestrial Links</u> animal species, erosion, fire, insects and disease, windthrow and storm damage	<u>Hydrologic Links</u> habitat (spatial and temporal types, size, amount, distribution, and complexity); riparian vegetation; substrate sorting <u>Terrestrial Links</u> vegetation mosaic **Affected by** <u>Cultural/Social Links</u> attitudes, beliefs, and values; lifestyles and lifeways; population character-istics; economics and subsistence; material culture; invention <u>Hydrologic Links</u> flooding <u>Terrestrial Links</u> animal species, erosion, fire, insects and disease, windthrow and storm damage	<u>Hydrologic Links</u> channel morphology, habitat (spatial and temporal types, size, amount, distribution, and complexity); riparian vegetation; substrate sorting <u>Terrestrial Links</u> vegetation mosaic **Affected by** <u>Cultural/Social Links</u> all cultural/social elements <u>Hydrologic Links</u> flooding <u>Terrestrial Links</u> animal species, erosion, fire, insects and disease, windthrow and storm damage	<u>Hydrologic Links</u> channel morphology, riparian vegetation (future recruitment) <u>Terrestrial Links</u> vegetation mosaic (future recruitment) **Affected by** <u>Cultural/Social Links</u> economics and subsis-tence; invention and diffusion <u>Hydrologic Links</u> flooding <u>Terrestrial Links</u> erosion, fire	**Affected by**: N/A

Matrix of Hydrologic Ecosystem Elements - Hydrologic Hierarchy

Ecosystem Element	Site (No order)	Subwatershed (1-3 order)	Watershed (3-5 order)	River Basin (5-7 order)	Icthyological Province
Organic Debris (continued)	**Environmental Indicators** presence, abundance decay class, tracking movement	**Environmental Indicators** abundance and distribution across channel types; decay class; tracking movement	**Environmental Indicators** abundance and distribution across channel types and tributaries; decay class; tracking movement	**Environmental Indicators** abundance and distribution across tributaries; tracking movement	**Environmental Indicators** N/A
Plant Species-Riparian **(Component & Structure)**	**Description** species, canopy, plant associations **Relevance** Cultural/Social Links attitudes, beliefs and values; lifestyles and lifeways; economics and subsistence; material culture; invention Hydrologic Links bank stability, habitat, water (temperature), nutrient pathways, organic debris Terrestrial Links erosion, food webs, nutrient cycle	**Description** seral stage, crown closure, plant association, patches, stands **Relevance** Cultural/Social Links attitudes, beliefs and values; lifestyles and lifeways; population characteristics; economics and subsistence; material culture; invention and diffusion Hydrologic Links bank stability, habitat, water (temperature), nutrient pathways, organic debris (recruitment) Terrestrial Links erosion, food webs, nutrient cycle	**Description** seral stage, crown closure, plant association, subseries, patches, forest vs grassland **Relevance** Cultural/Social Links attitudes, beliefs and values; lifestyles and lifeways; land use and settlement patterns; social organization; population characteristics; economics and subsistence; invention and diffusion Hydrologic Links bank stability, habitat, water (temperature), nutrient pathways, organic debris (recruitment) Terrestrial Links erosion, food webs, nutrient cycle	**Description** forests vs grasslands **Relevance** Cultural/Social Links lifestyles and lifeways; land use and settlement patterns; social organization; population characteristics Hydrologic Links organic debris (quantity) Terrestrial Links erosion (hillslopestability), vegetation mosaic (cover)	**Description** forest vs grasslands **Relevance** Hydrologic Links plant species (ecosystem structure and composition) Terrestrial Links vegetation mosaic

Matrix of Hydrologic Ecosystem Elements - Hydrologic Hierarchy

Ecosystem Element	Site (No order)	Subwatershed (1-3 order)	Watershed (3-5 order)	River Basin (5-7 order)	Icthyological Province
Plant Species-Riparian (continued)	**Affected by** Atmospheric Links climate Cultural/Social Links attitudes, beliefs, and values; lifestyles and lifeways; invention Hydrologic Links flooding Terrestrial Links erosion, fire, geology, insects and disease, soils **Environmental Indicators** basal area, presence, absence, canopy closure	**Affected by** Atmospheric Links climate Cultural/Social Links attitudes, beliefs, and values; lifestyles and lifeways; population characteristics; invention Hydrologic Links flooding Terrestrial Links erosion, fire, geology, insects and disease, soils **Environmental Indicators** canopy closure, basal area, presence, absence	**Affected by** Atmospheric Links climate Cultural/Social Links attitudes, beliefs, and values; lifestyles and lifeways; land use and settlement patterns; social organization; population character-istics; economics and subsistence; invention and diffusion Hydrologic Links flooding Terrestrial Links erosion, fire, geology, insects and disease, soils **Environmental Indicators** ecoclassifica-tion, canopy closure, stand inventory	**Affected by** Atmospheric Links climate Cultural/Social Links attitudes, beliefs, and values; lifestyles and lifeways; land use and settlement patterns; social organization; population character-istics; diffusion Hydrologic Links flooding Terrestrial Links erosion, fire, geology, insects and disease, soils **Environmental Indicators** ecoclassifica-tion, canopy closure, stand inventory	**Affected by** Atmospheric Links climate Cultural/Social Links social organization; economics and subsistence Hydrologic Links hydrologic regime Terrestrial Links geology **Environmental Indicators** ecoclassification

Matrix of Hydrologic Ecosystem Elements - Hydrologic Hierarchy

Ecosystem Element	Site (No order)	Subwatershed (1-3 order)	Watershed (3-5 order)	River Basin (5-7 order)	Icthyological Province
Plant Species-Aquatic **(Component & Structure)**	**Description** species, cover (e.g., algae, diatoms, periphyton, millfoil) **Relevance** Cultural/Social Links Attitudes, beliefs, and values; lifestyles and lifeways; economics and subsistence; material culture; invention Hydrologic Links animal species (habitat), food web, nutrient path-ways **Affected by** Atmospheric Links climate Cultural/Social Links attitudes, beliefs, and values; lifestyles and lifeways; invention Hydrologic Links flooding	**Description** species' populations, assemblages, and communities **Relevance** Cultural/Social Links attitudes, beliefs, and values; lifestyles and lifeways; population characteristics; economics and subsistence; material culture; invention and diffusion Hydrologic Links animal species (habitat), food webs, nutrient pathways, water quality **Affected by** Atmospheric Links climate Cultural/Social Links attitudes, beliefs, and values; lifestyles and lifeways; population characteristics; invention	**Description** species' populations, assemblages, and communities **Relevance** Cultural/Social Links attitudes, beliefs, and values; lifestyles and lifeways; land use and settlement patterns; social organization; population character-istics; economics and subsistence; invention and diffusion Hydrologic Links animal species (habitat), food webs, nutrient pathways, water quality **Affected by** Atmospheric Links climate Cultural/Social Links attitudes, beliefs, and values; lifestyles and lifeways; land use and settlement patterns; social organization; population character-istics; economics	**Description** species' populations, assemblages, and communities **Relevance** Cultural/Social Links lifestyles and lifeways; land use and settlement patterns; social organiza-tion; population character-istics Hydrologic Links animal species (habitat, population viability); nutrient pathways; water quality **Affected by** Atmospheric Links climate Cultural/Social Links attitudes, beliefs, and values; lifestyles and lifeways; land use and settlement patterns; social organization; population characteristics;	**Description** species' populations, assemblages, and communities **Relevance** Hydrologic Links animal species (habitat, population viability); water quality **Affected by** Atmospheric Links climate Cultural/Social Links social organization; economics and subsistence Hydrologic Links hydrologic regime

Matrix of Hydrologic Ecosystem Elements - Hydrologic Hierarchy

Ecosystem Element	Site (No order)	Subwatershed (1-3 order)	Watershed (3-5 order)	River Basin (5-7 order)	Icthyological Province
Plant Species-Aquatic (continued)	Terrestrial Links erosion, fire, geology, insects and disease, soils **Environmental Indicators** abundance and distribution biomass, species composition, growth	Hydrologic Links flooding Terrestrial Links erosion, fire, geology, insects and disease, soils **Environmental Indicators** abundance and distribution biomass, species composition, growth	Cultural/Social Links (continued) and subsistence; invention and diffusion Hydrologic Links flooding Terrestrial Links erosion, fire, geology, insects and disease, soils **Environmental Indicators** abundance and distribution biomass, species composition, growth	Cultural/Social Links (continued) economics and subsistence; diffusion Hydrologic Links flooding Terrestrial Links erosion, fire, geology, insects and disease, soils **Environmental Indicators** abundance and distribution species composition, population demographics	Terrestrial Links geology **Environmental Indicators** abundance and distribution species composition, population demographics

Matrix of Hydrologic Ecosystem Elements - Hydrologic Hierarchy

Ecosystem Element	Site (No order)	Subwatershed (1-3 order)	Watershed (3-5 order)	River Basin (5-7 order)	Icthyological Province
Sediment **(Component &Structure)**	**Description** pore space, substrate composition and distribu-tion, bars	**Description** bars, channel braids, terraces, substrate compo-sition and distribution	**Description** bars, channel braids, floodplains, dominant substrate composition, mass slope failures and scarps	**Description** floodplains, large hillslope failures, channel braids, deltas	**Description** N/A
	Relevance <u>Cultural/Social Links</u> attitudes beliefs, and values; lifestyles and lifeways; economics and subsistence <u>Hydrologic Links</u> animal and plant species (habitat quality and availability); nutrient pathways	**Relevance** <u>Cultural/Social Links</u> attitudes beliefs, and values; lifestyles and lifeways; population character-istics; economics and subsistence; invention <u>Hydrologic Links</u> animal and plant species (habitat quality, availabil-ity, and diversity); nutrient pathways; water quality	**Relevance** <u>Cultural/Social Links</u> attitudes beliefs, and values; lifestyles and lifeways; land use and settlement patterns; social organization; population character-istics; economics and subsistence; invention and diffusion <u>Hydrologic Links</u> animal and plant species (habitat quality, availabil-ity, and diversity); channel morphology; nutrient pathways; water quality	**Relevance** <u>Cultural/Social Links</u> attitudes beliefs, and values; lifestyles and lifeways; land use and settlement patterns; social organization; population character-istics; economics and subsistence; invention and diffusion <u>Hydrologic Links</u> animal and plant species (habitat quality, availabil-ity, and diversity); channel morphology; water quality	**Relevance** N/A
	Affected by <u>Atmospheric Links</u> climate	**Affected by** <u>Atmospheric Links</u> climate	**Affected by** <u>Atmospheric Links</u> climate	**Affected by** <u>Atmospheric Links</u> climate	**Affected by** N/A

Matrix of Hydrologic Ecosystem Elements - Hydrologic Hierarchy

Ecosystem Element	Site (No order)	Subwatershed (1-3 order)	Watershed (3-5 order)	River Basin (5-7 order)	Icthyological Province
Sediment (continued)	<u>Cultural/Social Links</u> lifestyles and lifeways; economics and subsistence; material culture; invention <u>Hydrologic Links</u> flooding <u>Terrestrial Links</u> erosion, fire, geology, soils **Environmental Indicators** V*, substrate size (pebble counts), embeddedness, turbidity	<u>Cultural/Social Links</u> lifestyles and lifeways; economics and subsistence; material culture; invention <u>Hydrologic Links</u> flooding <u>Terrestrial Links</u> erosion, fire, geology, soils **Environmental Indicators** V*, substrate size (pebble counts), embeddedness, riffle-armor index, turbidity	<u>Cultural/Social Links</u> all cultural/social elements <u>Hydrologic Links</u> flooding <u>Terrestrial Links</u> erosion, fire, geology, soils **Environmental Indicators** V*, substrate size (pebble counts), embeddedness, riffle-armor index, channel depositional features (areal extent)	<u>Cultural/Social Links</u> all cultural/social elements <u>Hydrologic Links</u> flooding, hydrologic regime <u>Terrestrial Links</u> erosion, fire, geology, soils **Environmental Indicators** channel depositional features and sediment sources	**Environmental Indicators** N/A
Water **(Component & Structure)**	**Description** velocity, turbulence, channels, ponds, springs, bogs, subsurface flow	**Description** discharge, stream channels, lakes, ponds, subsurface flow	**Description** drainage network, lakes	**Description** drainage network and density, lakes, aquifers	**Description** drainage network and density, lakes, aquifers

Matrix of Hydrologic Ecosystem Elements - Hydrologic Hierarchy

Ecosystem Element	Site (No order)	Subwatershed (1-3 order)	Watershed (3-5 order)	River Basin (5-7 order)	Icthyological Province
Water (continued)	**Relevance** Cultural/Social Links attitudes, beliefs, and values; lifestyles and lifeways; economics and subsistence; material culture; invention Hydrologic Links animal species (micro-habitat availability and quantity) **Affected by** Atmospheric Links climate Cultural/Social Links attitudes, beliefs, and values; lifestyles and lifeways; economics and subsistence; material culture; invention Hydrologic Links flooding, hydrologic regime, organic debris (beaver dam), local hydraulics, sediment	**Relevance** Cultural/Social Links attitudes, beliefs, and values; lifestyles and lifeways; economics and subsistence; material culture; invention Hydrologic Links animal species (habitat abundance, distribution, and quality) **Affected by** Atmospheric Links climate Cultural/Social Links attitudes, beliefs, and values; lifestyles and lifeways; social organization; economics and subsistence; material culture; invention Hydrologic Links flooding, hydrologic regime	**Relevance** Cultural/Social Links all cultural/social elements Hydrologic Links animal species (habitat abundance, distribution, and quality) **Affected by** Atmospheric Links climate Cultural/Social Links all cultural/social elements Hydrologic Links flooding, hydrologic regime	**Relevance** Cultural/Social Links all cultural/social elements Hydrologic Links animal species (habitat abundance, distribution, and quality) **Affected by** Atmospheric Links climate Cultural/Social Links all cultural/social elements Hydrologic Links flooding, hydrologic regime	**Relevance** Cultural/Social Links all cultural/social elements Hydrologic Links animal species (habitat abundance, distribution, and quality) **Affected by** Atmospheric Links climate Cultural/Social Links all cultural/social elements Hydrologic Links flooding, hydrologic regime

Matrix of Hydrologic Ecosystem Elements - Hydrologic Hierarchy

Ecosystem Element	Site (No order)	Subwatershed (1-3 order)	Watershed (3-5 order)	River Basin (5-7 order)	Icthyological Province
Water (continued)	**Environmental Indicators** velocity, turbulence, quantity	**Environmental Indicators** discharge, volume, depth	**Environmental Indicators** drainage density, discharge	**Environmental Indicators** drainage density, discharge	**Environmental Indicators** drainage density, discharge

Matrix of Key Ecosystem Elements - Terrestrial Hierarchy

Ecosystem Element	Land Unit	Landscape	Subregion	Ecoregion
Animal Species **(Component)**	**Description** individuals, breeding pairs, small subpopulations **Relevance** <u>Cultural/Social Links</u> land use and settlement patterns; economics and subsistence; material culture <u>Hydrologic Links</u> animal and plant species (aquatic habitat structures: type, seasonal dynamics); food web; nutrient pathways <u>Terrestrial Links</u> nutrient transport and cycling; pollination/seed dispersal; soil productivity (porosity and organic matter); other animal species (predation, competition, mutualism); vegetation mosaic (seral stage, vigor, gap dynamics); plant species (distribution and abundance); fire regimes	**Description** individuals, breeding pairs, small subpopulations **Relevance** <u>Cultural/Social Links</u> attitudes, beliefs, and values; lifestyles and lifeways; land use and settlement patterns; social organization; economics and subsistence; material culture; invention and diffusion <u>Hydrologic Links</u> animal and plant species (aquatic habitat structures: type, seasonal dynamics); food web; nutrient pathways <u>Terrestrial Links</u> animal and plant species (occurrence, distribution, abundance, and vigor); nutrient transport and cycling; pollination/seed dispersal; soil productivity (porosity and organic matter)	**Description** populations; entire ranges of races, subspecies, or species **Relevance** <u>Cultural/Social Links</u> attitudes, beliefs, and values; lifestyles and lifeways; land use and settlement patterns; social organization; economics and subsistence; material culture; invention and diffusion <u>Terrestrial Links</u> animal and plant species (occurrence, distribution, abundance, and vigor); vegetation mosaic (seral stage proportion and vigor)	**Description** species subspecies, or race ranges **Relevance** <u>Cultural/Social Links</u> attitudes, beliefs, and values; lifestyles and lifeways; land use and settlement patterns; social organization; economics and subsistence; material culture; invention and diffusion <u>Terrestrial Links</u> animal species distribution and abundance

Matrix of Key Ecosystem Elements - Terrestrial Hierarchy

Ecosystem Element	Land Unit	Landscape	Subregion	Ecoregion
Animal Species (continued)	**Affected by** Cultural/Social Links all cultural/social elements Hydrologic Links animal and plant species (aquatic habitat structures: type, seasonal dynamics); food web; quantity, quality, and availability of water Terrestrial Links other animal species (predation, competition, mutualism, food); vegetation mosaic (seral stage and species composition); plant species (distribution, abundance, vigor); disease; special habitat features **Environmental Indicators** species occurrence and abundance; habitat condition (including special features); physiological condition; reproductive success; extent of native local germplasm	**Affected by** Cultural/Social Links all cultural/social elements Terrestrial Links animal and plant species (occurrence, distribution and abundance); vegetation mosaic (seral stage proportion) **Environmental Indicators** species occurrence, distribution, and abundance; habitat and landscape condition; species assemblages; demographics (fecundity, mortality, age structure, sex ratios); physiological condition; extent of native local germplasm, extent and distribution of native local gene pools	**Affected by** Cultural/Social Links all cultural/social elements Terrestrial Links animal and plant species (occurrence, distribution, abundance, and vigor); vegetation mosaic (connectivity and seral stage distribution) **Environmental Indicators** species occurrence, distribution, abundance and demographics; species assemblages; landscape condition; extent and distribution of races, subspecies and/or ecotypes	**Affected by** Cultural/Social Links all cultural/social elements Terrestrial Links animal species (distribution, abundance, and vigor); vegetation mosaic (connectivity and seral stage distribution) **Environmental Indicators** species distribution, abundance, and demographics; species assemblages; landscape condition; extent and distribution of races, subspecies and/or ecotypes

Matrix of Key Ecosystem Elements - Terrestrial Hierarchy

Ecosystem Element	Land Unit	Landscape	Subregion	Ecoregion
Damage **(Process)**	**Description** windthrow and storm damage result when trees or other plants are uprooted or broken during storms **Relevance** Cultural/Social Links social organization; economics and subsistence; material culture Hydrologic Links animal and plant species (habitat structure); nutrient pathways Terrestrial Links animal and plant species; fire behavior; organic debris; soil productivity; vegetation mosaic (patch shape, size, gap dynamics, forest structure) **Affected by** Atmospheric Links climate	**Description** windthrow and storm damage result across landscapes when trees or other plants are up-rooted or broken during storms **Relevance** Cultural/Social Links social organization; economics and subsistence; material culture Hydrologic Links animal and plant species (habitat structure); nutrient pathways Terrestrial Links animal and plant species; fire behavior; organic debris; soil productivity; vegetation mosaic (patch shape, size, gap dynamics, forest structure) **Affected by** Atmospheric Links climate	**Description** windthrow and storm damage across subregions **Relevance** Cultural/Social Links social organization; economics and subsistence; material culture Hydrologic Links animal and plant species (habitat) Terrestrial Links animal and plant species; organic debris; vegetation mosaic **Affected by** Atmospheric Links climate	**Description** windthrow and storm damage across ecoregions **Relevance** Cultural/Social Links social organization; economics and subsistence; material culture Hydrologic Links animal and plant species (populations) Terrestrial Links animal and plant species (populations); organic debris; vegetation mosaic **Affected by** Atmospheric Links climate

Matrix of Key Ecosystem Elements - Terrestrial Hierarchy

Ecosystem Element	Land Unit	Landscape	Subregion	Ecoregion
Damage (continued)	Cultural/Social Links land use and settlement patterns; material culture; invention and diffusion Hydrologic Links riparian plants Terrestrial Links plant species; vegetation mosaic (patch shape, size, gap dynamics) **Environmental Indicators** distribution; species affected; patch size; tons/acre; number of plants/area	Cultural/Social Links land use and settlement patterns; material culture; invention and diffusion Hydrologic Links riparian plants Terrestrial Links plant species; vegetation mosaic (patch shape, size, gap dynamics) **Environmental Indicators** distribution; species affected; patch size	Cultural/Social Links land use and settlement patterns; material culture; invention and diffusion Hydrologic Links riparian plants Terrestrial Links plant species; vegetation mosaic (patch shape, size, gap dynamics) **Environmental Indicators** distribution; species affected; patch size	Cultural/Social Links land use and settlement patterns; material culture; invention and diffusion Terrestrial Links vegetation mosaic **Environmental Indicators** disturbance pattern; storm track; patch size shifts
Erosion **(Process)**	**Description** slumps, sheetwash, rills, gullies, landslides, exfoliation, piping **Relevance** Hydrologic Links animal and plant species (habitat); channel morphology (bank stability); sedimentation; water quality	**Description** gullies; mass movements and slope failures; depositional features; debris flows **Relevance** Cultural/Social Links lifestyles and lifeways; economics and subsistence	**Description** mass movements and slope failures; depositional features; debris flows **Relevance** Cultural/Social Links lifestyles and lifeways; economics and subsistence	**Description** several mass movements, slope failures, or debris flows **Relevance** Cultural/Social Links lifestyles and lifeways; social organization; economics and subsistence

Matrix of Key Ecosystem Elements - Terrestrial Hierarchy

Ecosystem Element	Land Unit	Landscape	Subregion	Ecoregion
Erosion (continued)	Terrestrial Links animal and plant species (habitat); soils (productivity, stability, hydrology); vegetation mosaic (seral stage, patch size) **Affected by** Atmospheric Links climate Cultural/Social Links lifestyles an d lifeways; social organization; economics and subsistence; material culture; invention Hydrologic Links flooding Terrestrial Links fire, geology, soil type	Hydrologic Links animal and plant species (habitat); channel morphology (bank stability, instream features); sedimentation; water quality Terrestrial Links animal and plant species (habitat); soils (productivity, stability, hydrology); vegetation mosaic (seral stage, patch size) **Affected by** Atmospheric Links climate Cultural/Social Links lifestyles an d lifeways; land use and settlement patterns; social organization; economics and subsistence; material culture; invention and diffusion Hydrologic Links flooding Terrestrial Links fire, geology, soil type	Hydrologic Links animal and plant species (habitat); channel morphology (bank stability, instream features); water quality Terrestrial Links animal and plant species (habitat); soils (productivity, stability, hydrology); vegetation mosaic (seral stage, patch size) **Affected by** Atmospheric Links climate Cultural/Social Links lifestyles an d lifeways; land use and settlement patterns; social organization; economics and subsistence; material culture; invention and diffusion Hydrologic Links flooding Terrestrial Links fire, geology	Hydrologic Links animal and plant species; channel morphology; water quality Terrestrial Links animal and plant species; soils; vegetation mosaic **Affected by** Atmospheric Links climate Cultural/Social Links lifestyles an d lifeways; land use and settlement patterns; social organization; economics and subsistence; material culture; invention and diffusion Hydrologic Links flooding Terrestrial Links fire, geology

Matrix of Key Ecosystem Elements - Terrestrial Hierarchy

Ecosystem Element	Land Unit	Landscape	Subregion	Ecoregion
Erosion (continued)	**Environmental Indicators** presence and absence; volume and extent of material moved; depositional features; plant pedestals; slide paths; soil characteristics (infiltration rate, permeability, erosion hazard, slope); vegetation type and cover	**Environmental Indicators** volume and areal extent of material moved; depositional features; slide or flow paths; fractures; soil type; vegetation type and cover; slope; debris flow hazard	**Environmental Indicators** volume, areal extent, frequency, and distribution of material moved; soil series; geologic hazard	**Environmental Indicators** volume, areal extent, frequency, and distribution of material moved; soil series; geologic hazard
Fire **(Process)**	**Description** combustion of organic material (plants, woody debris, detritus, biotic organisms) and chemical compounds (NH4, C6H12O6, etc.) **Relevance** <u>Atmospheric Links</u> particulates <u>Cultural/Social Links</u> all cultural/social elements <u>Hydrologic Links</u> animal and plant species (habitats); nutrient pathways; organic debris; sedimentation; water (chemistry, temperature)	**Description** combustion of organic material (plants, woody debris, detritus, biotic organisms) and chemical compounds (NH4, C6H12O6, etc.) **Relevance** <u>Atmospheric Links</u> particulates, nitrogen oxides, sulfur dioxides <u>Cultural/Social Links</u> all cultural/social elements <u>Hydrologic Links</u> animal and plant species and populations (habitat); nutrient pathways (release); organic	**Description** combustion of organic material (plants, woody debris, detritus, biotic organisms) and chemical compounds (NH4, C6H12O6, etc.) **Relevance** <u>Atmospheric Links</u> particulates, nitrogen oxides, sulfur dioxides <u>Cultural/Social Links</u> all cultural/social elements <u>Hydrologic Link</u> animal and plant species (viability); hydrologic regime	**Description** combustion of organic material (plants, woody debris, detritus, biotic organisms) and chemical compounds (NH4, C6H12O6, etc.) **Relevance** <u>Atmospheric Links</u> particulates, nitrogen oxides, sulfur dioxides <u>Cultural/Social Links</u> all cultural/social elements <u>Hydrologic Links</u> animal and plant species; hydrologic regime

Matrix of Key Ecosystem Elements - Terrestrial Hierarchy

Ecosystem Element	Land Unit	Landscape	Subregion	Ecoregion
Fire (continued)	<u>Terrestrial Links</u> animal and plant species (direct and habitat); erosion (soil protection); nutrient cycles; organic debris; soils (productivity, infiltration rates); vegetation mosaic	<u>Hydrologic Links</u> (continued) debris; sedimentation; water (chemistry, temperature) <u>Terrestrial Links</u> animal and plant species and populations; erosion (soil protection); nutrient cycles; organic debris; soils (productivity, infiltration rates); vegetation mosaic	<u>Terrestrial Link</u> animal and plant species (viability); erosion (soil protection); vegetation mosaic	<u>Terrestrial Links</u> animal and plant species; vegetation mosaic
	Affected by <u>Atmospheric Links</u> climate	**Affected by** <u>Atmospheric Links</u> climate	**Affected by** <u>Atmospheric Links</u> climate	**Affected by** <u>Atmospheric Links</u> climate
	<u>Cultural/Social Links</u> all cultural/social elements	<u>Cultural/Social Links</u> all cultural/social elements	<u>Cultural/Social Links</u> all cultural/social elements	<u>Cultural/Social Links</u> all cultural/social elements
	<u>Hydrologic Links</u> organic debris; riparian plants (fuel loads, plant phenology)	<u>Hydrologic Links</u> organic debris; riparian plants (fuel loads, plant phenology)	<u>Hydrologic Links</u> organic debris; riparian plants (fuel loads, plant phenology)	<u>Hydrologic Links</u> organic debris; riparian plants (fuel loads, plant phenology)
	<u>Terrestrial Links</u> plant species (fuel loads, plant phenology); organic debris; soils (moisture); topography	<u>Terrestrial Links</u> plant species (fuel loads, plant phenology); organic debris; soils (moisture); topography; vegetation mosaic	<u>Terrestrial Links</u> plant species (fuel loads, plant phenology); organic debris; soils (moisture); topography; vegetation mosaic	<u>Terrestrial Links</u> plant species (fuel loads, plant phenology); organic debris; soils (moisture); topography; vegetation mosaic

Matrix of Key Ecosystem Elements - Terrestrial Hierarchy

Ecosystem Element	Land Unit	Landscape	Subregion	Ecoregion
Fire (continued)	**Environmental Indicators** intensity, duration, and magnitude: severity (L,M,H,E); size; distribution (location in landscape)	**Environmental Indicators** intensity, duration, and magnitude: severity (L,M,H,E); size; distribution (location in landscape); return rate; seasonality	**Environmental Indicators** intensity, duration, and magnitude: severity (L,M,H,E); size; distribution (location in landscape); return rate; seasonality	**Environmental Indicators** intensity, duration, and magnitude: severity (L,M,H,E); size; distribution (location in landscape); return rate; seasonality
Food Web **(Component & Structure)**	**Description** network of interdependent organisms making up the biotic component of a nutrient pathway **Relevance** <u>Cultural/Social Links</u> all cultural/social element <u>Hydrologic Links</u> animal and plant species; nutrient pathways <u>Terrestrial Links</u> animal species (community diversity—micro and macro,	**Description** network of interdependent organisms making up the biotic component of a nutrient pathway **Relevance** <u>Cultural/Social Links</u> all cultural/social elements <u>Hydrologic Links</u> animal and plant species; nutrient pathways <u>Terrestrial Links</u> animal species (community diversity—micro and macro,	**Description** network of interdependent organisms making up the biotic component of a nutrient pathway **Relevance** <u>Cultural/Social Links</u> all cultural/social elements <u>Hydrologic Links</u> animal species (predator/ prey relation ships, community stability and resiliency); nutrient pathways; plant species <u>Terrestrial Links</u> animal species (predator/prey relationships, community	**Description** network of interdependent organisms making up the biotic component of a nutrient pathway **Relevance** <u>Cultural/Social Links</u> all cultural/social elements <u>Hydrologic Links</u> animal species (predator/prey relation ships, community stability and resiliency, food availability); nutrient path-ways; plant species <u>Terrestrial Links</u> animal species (predator/prey relationships, community

Matrix of Key Ecosystem Elements - Terrestrial Hierarchy

Ecosystem Element	Land Unit	Landscape	Subregion	Ecoregion
Food Web (continued)	predator prey relationships); nutrient cycling ; plant species **Affected by** Atmospheric Links climate Cultural/Social Links all cultural/social elements Hydrologic Links animal and plant species (assemblages, population dynamics); flooding Terrestrial Links animal and plant species (assemblages, population dynamics); erosion; fire; nutrient cycles (availability and exchange) **Environmental Indicators** plankton and macroinvertebrate samples; diversity indices	predator prey relationships, stability and resiliency); nutrient cycling ; plant species **Affected by** Atmospheric Links climate Cultural/Social Links all cultural/social elements Hydrologic Links animal and plant species (assemblages, population dynamics); flooding Terrestrial Links animal and plant species (assemblages, population dynamics); erosion; fire; nutrient cycles (availability and exchange) **Environmental Indicators** producers vs predator ratios; species assemblages	stability and resiliency); nutrient cycling ; plant species **Affected by** Atmospheric Links climate Cultural/Social Links all cultural/social elements Hydrologic Links animal and plant species (assemblages, population dynamics); flooding Terrestrial Links animal and plant species (assemblages, population dynamics); erosion; fire; nutrient cycles (availability and exchange) **Environmental Indicators** species assemblages	stability and resiliency, food availability); nutrient cycling ; plant species **Affected by** Atmospheric Links climate Cultural/Social Links all cultural/social elements Hydrologic Links animal and plant species (assemblages, migration, population dynamics); flooding Terrestrial Links animal and plant species (assemblages, migration, population dynamics); erosion; fire; nutrient cycles (availability and exchange) **Environmental Indicators** species assemblages

Matrix of Key Ecosystem Elements - Terrestrial Hierarchy

Ecosystem Element	Land Unit	Landscape	Subregion	Ecoregion
Genetic Diversity* **(Component & Structure and Process)**	**Description** genetic diversity within individuals (gametes, juveniles and adults) (i.e., genotypes) and within family clusters genetic drift, mutation, and recombination mating behavior	**Description** genetic diversity within and between family clusters; interaction between individuals in a population gene flow, natural selection, and influence of historic events	**Description** clusters and patterns of grouped genotypes, variants, races, subspecies, and species; effects of historical events and their impact on population resilience and adaptability cumulative effects of gene flow, genetic drift, and natural selection; influence of historical events	**Description** geographic races, subspecies, species, genera, families; effects of historical events and their impact on population resilience and adaptability cumulative effects of gene flow, genetic drift, and natural selection; influence of historical events
	Relevance <u>Cultural/Social Links</u> attitudes, beliefs, and values; lifestyles and lifeways <u>Hydrologic Links</u> animal and plant species (individual is basic package of genetic diversity); food web <u>Terrestrial Links</u> animal and plant species (individual is basic package of genetic diversity); food web	**Relevance** <u>Cultural/Social Links</u> all cultural/social elements <u>Hydrologic Links</u> animal and plant species (environmental gradients in genetic diversity emerge); food web <u>Terrestrial Links</u> animal and plant species (environmental gradients in genetic diversity emerge); food web	**Relevance** <u>Cultural/Social Links</u> all cultural/social elements <u>Hydrologic Links</u> animal and plant species (population structure and geneflow, adaptive capabilities); food web <u>Terrestrial Links</u> animal and plant species (population structure and geneflow, adaptive capabilities); food web	**Relevance** <u>Cultural/Social Links</u> all cultural/social elements <u>Hydrologic Links</u> animal and plant species (viability, adaptive capabilities) <u>Terrestrial Links</u> animal and plant species (viability, adaptive capabilities)
	Affected by <u>Cultural/Social Links</u> attitudes, beliefs, and values	**Affected by** <u>Cultural/Social Links</u> all cultural/social elements	**Affected by** <u>Cultural/Social Links</u> all cultural/social elements	**Affected by** <u>Cultural/Social Links</u> all cultural/social elements

Matrix of Key Ecosystem Elements - Terrestrial Hierarchy

Ecosystem Element	Land Unit	Landscape	Subregion	Ecoregion
Genetic Diversity* (continued)	Hydrologic Links animal and plant species (competition , predation); channel morphology (type); water quality	Hydrologic Links animal and plant species (competition , predation); channel morphology (type); water quality	Hydrologic Links animal and plant species (competition , predation, location/ niche); channel morphology (type); water quality	Hydrologic Links animal and plant species (competition , predation, location/ niche); channel morphology (type); water quality
	Terrestrial Links animal and plant species (competition , predation); vegetation mosaic (disturbance regimes, harvest regimes)	Terrestrial Links animal and plant species (competition , predation); vegetation mosaic (disturbance regimes, harvest regimes)	Terrestrial Links animal and plant species (competition , predation location/ niche); vegetation mosaic (disturbance regimes, harvest regimes)	Terrestrial Links animal and plant species (competition , predation location/ niche); vegetation mosaic (disturbance regimes, harvest regimes)
	Environmental Indicators species composition; number of individuals/age class; population size; spatial distribution; systematic removal of particular phenotypes or from geographic location or habitat; effective population size; sex ratio; dispersal rates; spatial pattern of mating system; hybrid occurrence	**Environmental Indicators** species composition; effective population size; gene flow; genotype and phenotype frequencies; population distribution and structure; spatial arrangement of genotypic clusters; location in the landscape; reproductive success; number of genetic patches; hybrid occurrence	**Environmental Indicators** species composition; distribution, boundaries, and extent of races, subspecies, ecotypes; gene flow; population distribution and structure; reproductive success; number of genetic patches; number and spatial pattern of ecotypes	**Environmental Indicators** species composition; distribution, boundaries and extent of races, subspecies, ecotypes; gene flow; population distribution and structure; reproductive success; number of subspecies, number of genera, number of families

* The genetic diversity element may be applied to animals and plants in both the Terrestrial and Hydrologic Hierarchies.

Matrix of Key Ecosystem Elements - Terrestrial Hierarchy

Ecosystem Element	Land Unit	Landscape	Subregion	Ecoregion
Insect Infestation (Process)	**Description** some insects kill or weaken trees/shrubs or groups of trees/shrubs, resulting in alterations in the vegetative mosaic at this scale **Relevance** Cultural/Social Links land use and settlement patterns; economics and subsistence Hydrologic Links animal species (habitat); organic debris; plant species Terrestrial Links animal species (individuals, populations, habitat); fire (behavior); organic debris; plant species (vigor, composition, structure); vegetation mosaic **Affected by** Cultural/Social Links attitudes, beliefs, and values; land use and settlement patterns	**Description** some insects kill or groups of trees/shrubs with resultant changes in seral stage, distribution of plant species, and distribution and amount of coarse woody debris **Relevance** Cultural/Social Links land use and settlement patterns; economics and subsistence Hydrologic Links animal species (habitat); organic debris; plant species Terrestrial Links animal species; vegetation mosaic; fire dynamics; plant species (vigor, composition, structure); organic debris; vegetation mosaic **Affected by** Cultural/Social Links attitudes, beliefs, and values; land use and settlement patterns; social organization; invention and diffusion	**Description** changes in vegetative patterns if disturbance is on a subregional scale **Relevance** Cultural/Social Links land use and settlement patterns; economics and subsistence Hydrologic Links animal species (habitat); plant species Terrestrial Links animal species (habitat connectivity); fire regimes; plant species (gene flow for species specific pathogens); vegetation mosaic (connectivity) **Affected by** Cultural/Social Links attitudes, beliefs, and values; land use and settlement patterns; social organization; invention and diffusion	**Description** widespread periodic disturbance by insects can affect vegetative patterns on a broad scale **Relevance** Cultural/Social Links land use and settlement patterns; economics and subsistence Hydrologic Links animal species (habitat); plant species Terrestrial Links animal species (habitat connectivity); fire regime; plant species (gene flow for species specific pathogens); vegetation mosaic (connectivity) **Affected by** Cultural/Social Links attitudes, beliefs, and values; land use and settlement patterns; social organization; invention and diffusion

Matrix of Key Ecosystem Elements - Terrestrial Hierarchy

Ecosystem Element	Land Unit	Landscape	Subregion	Ecoregion
Insect Infestation (continued)	Hydrologic Links plant species Terrestrial Links fire regimes; plant species (vigor) **Environmental Indicators** severity and size; distribution; species affected	Hydrologic Links plant species Terrestrial Links vegetation mosaic; fire regimes; plant species (vigor) **Environmental Indicators** severity and size; distribution; species affected	Terrestrial Links vegetation mosaic (connectivity); fire regimes **Environmental Indicators** severity; size; distribution; species affected; return rate	Terrestrial Links vegetation mosaic (connectivity); fire regimes **Environmental Indicators** occurrence patterns (temporal and spatial)
Nutrient Cycle **(Process)**	**Description** the routes and rates of nutrient flow through an ecosystem **Relevance** Cultural/Social Links land use and settlement patterns; population characteristics; economics and subsistence Hydrologic Links nutrient pathways Terrestrial Links animal and plant species (nitrogen cycle, carbon cycle); soils (biota; nutrient pools, sinks, sources)	**Description** the routes and rates of nutrient flow through an ecosystem **Relevance** Atmospheric Links nitrogen oxides, sulfur dioxide Cultural/Social Links lifestyles and lifeways; land use and settlement patterns; population characteristics; economics and subsistence; invention and diffusion Hydrologic Links nutrient pathways	**Description** the routes and rates of nutrient flow through an ecosystem **Relevance** Atmospheric Links nitrogen oxides, sulfur dioxide Cultural/Social Links lifestyles and lifeways; land use and settlement patterns; population characteristics; economics and subsistence; invention and diffusion Hydrologic Links nutrient pathways	**Description** the routes and rates of nutrient flow through an ecosystem **Relevance** Atmospheric Links nitrogen oxides, sulfur dioxide Cultural/Social Links lifestyles and lifeways; land use and settlement patterns; population characteristics; economics and subsistence; invention and diffusion Hydrologic Links nutrient pathways

Matrix of Key Ecosystem Elements - Terrestrial Hierarchy

Ecosystem Element	Land Unit	Landscape	Subregion	Ecoregion
Nutrient Cycle (continued)	 **Affected by** Atmospheric Links climate, nutrient input Cultural/Social Links lifestyles and lifeways; economics and subsistence Hydrologic Links animal and plant species, flooding, nutrient pathways Terrestrial Links animal and plant species, erosion, fire, insect infestation, organic debris, pathogens, soil productivity, vegetation mosaic, windthrow and storm damage	Terrestrial Links animal and plant species (nitrogen cycle, carbon cycle); soils (biota; nutrient pools, sinks, sources) **Affected by** Atmospheric Links climate, nutrient input Cultural/Social Links lifestyles and lifeways; land use and settlement patterns; social organizations; population characteristics; economics and subsistence; material culture; invention and diffusion Hydrologic Links animal and plant species, flooding Terrestrial Links animal and plant species, erosion, fire, insect infestation, organic debris, pathogens, soil productivity, vegetation mosaic, windthrow and storm damage	Terrestrial Links animal and plant species (nitrogen cycle, carbon cycle); soils (biota; nutrient pools, sinks, sources) **Affected by** Atmospheric Links climate, net nutrient input Cultural/Social Links lifestyles and lifeways; land use and settlement patterns; social organizations; population characteristics; economics and subsistence; material culture; invention and diffusion Hydrologic Links animal and plant species, flooding Terrestrial Links animal and plant species, erosion, fire, insect infestation, organic debris, pathogens, soil productivity, vegetation mosaic, windthrow and storm damage	Terrestrial Links animal and plant species (nitrogen cycle, carbon cycle); soils (biota; nutrient pools, sinks, sources) **Affected by** Atmospheric Links climate, net nutrient input Cultural/Social Links lifestyles and lifeways; land use and settlement patterns; social organizations; population characteristics; economics and subsistence; material culture; invention and diffusion Hydrologic Links animal and plant species, flooding Terrestrial Links animal and plant species, erosion, fire, insect infestation, organic debris, pathogens, soil productivity, vegetation mosaic, windthrow and storm damage

Matrix of Key Ecosystem Elements - Terrestrial Hierarchy

Ecosystem Element	Land Unit	Landscape	Subregion	Ecoregion
Nutrient Cycle (continued)	**Environmental Indicators** biotic populations and activity levels; concentration, rates of change, and budgets of physical and chemical constituents (e.g., pH, conductivity, nitrogen) of the air, soil, and water	**Environmental Indicators** biotic populations and activity levels; concentration, rates of change, and budgets of physical and chemical constituents (e.g., pH, conductivity, nitrogen) of the air, soil, and water	**Environmental Indicators** net biotic productivity; concentration, rates of change, and budgets of physical and chemical constituents (e.g., pH, conductivity, nitrogen) of the air, soil, and water	**Environmental Indicators** net biotic productivity; concentration, rates of change, and budgets of physical and chemical constituents (e.g., pH, conductivity, nitrogen) of the air, soil, and water
Organic Debris-Coarse Woody **(Component & Structure)**	**Description** standing (snags) and down (logs) woody debris **Relevance** <u>Hydrologic Links</u> animal species (habitat); channel morphology; nutrient pathways; plant species (habitat, recruitment of material); water (temperature) <u>Terrestrial Links</u> animal species (habitat); fire behavior; nutrient cycles; plant species (habitat, recruitment of material); soil productivity	**Description** standing (snags) and down (logs) woody debris **Relevance** <u>Cultural/Social Links</u> lifestyles and lifeways; land use and settlement patterns; social organizations; economics and subsistence <u>Hydrologic Links</u> animal species (habitat, local population viability); plant species (habitat, local population viability; recruitment of material); water (temperature)	**Description** standing (snags) and down (logs) woody debris **Relevance** <u>Cultural/Social Links</u> lifestyles and lifeways; land use and settlement patterns; social organizations; economics and subsistence <u>Hydrologic Links</u> animal species (habitat, population viability) <u>Terrestrial Links</u> animal species (habitat, population viability)	**Description** standing (snags) and down (logs) woody debris **Relevance** <u>Cultural/Social Links</u> lifestyles and lifeways; land use and settlement patterns; social organizations; economics and subsistence <u>Hydrologic Links</u> gene flow (considerations for large range species) <u>Terrestrial Links</u> gene flow (considerations for large range species)

Matrix of Key Ecosystem Elements - Terrestrial Hierarchy

Ecosystem Element	Land Unit	Landscape	Subregion	Ecoregion
Organic Debris-Coarse Woody (continued)		<u>Terrestrial Links</u> animal species (habitat, local population viability); fire dynamics; plant species (habitat, local population viability, recruitment of material); soil productivity		
	Affected by <u>Cultural/Social Links</u> lifestyles and lifeways; economics and subsistence <u>Hydrologic Links</u> flooding <u>Terrestrial Links</u> fire behavior; insect infestations; pathogens and disease; plant species (habitat); soil productivity; windthrow and storm damage; soil productivity	**Affected by** <u>Cultural/Social Links</u> all cultural/social elements <u>Hydrologic Links</u> flooding <u>Terrestrial Links</u> fire behavior; insect infestations; pathogens and disease; plant species (habitat, local population viability); soil productivity; windthrow and storm damage; soil productivity	**Affected by** <u>Atmospheric Links</u> climate <u>Cultural/Social Links</u> all cultural/social elements <u>Hydrologic Links</u> flooding <u>Terrestrial Links</u> fire regimes; insect infestations; pathogens and disease	**Affected by** <u>Atmospheric Links</u> climate <u>Cultural/Social Links</u> all cultural/social elements <u>Terrestrial Links</u> fire regimes; insect infestations; pathogens and disease
	Environmental Indicators down material: volume, number of pieces, tons/acre, distribution (vertical and horizontal continuity); all measures by species, size class and decay class; standing material (snag density	**Environmental Indicators** down material: volume, number of pieces, tons/acre, distribution (vertical and horizontal continuity); all measures by species, size class, and decay class; standing material (snag density	**Environmental Indicators** connectivity of landscape; size of suitable habitat patches	**Environmental Indicators** connectivity of landscape; size of suitable habitat patches

Matrix of Key Ecosystem Elements - Terrestrial Hierarchy

Ecosystem Element	Land Unit	Landscape	Subregion	Ecoregion
Organic Debris-Coarse Woody (continued)	**Environmental Indicators** (continued) and distribution by dbh, height, species, decay class); green trees available for recruitment	**Environmental Indicators** (continued) and distribution by dbh, height, species, decay class); green trees available for recruitment		
Organic Debris-Fine Organic Matter **(Component & Structure)**	**Description** small pieces of dead plant material on the surface of the soil, generally less than three inches in diameter **Relevance** Hydrologic Links food web; sedimentation; water quality Terrestrial Links animal and plant species (habitat); erosion (soil protection); fire behavior; nutrient cycling; soil productivity (temperature, moisture)	**Description** small pieces of dead plant material on the surface of the soil, generally less than three inches in diameter **Relevance** Cultural/Social Links lifestyles and lifeways; land use and settlement patterns; social organizations; economics and subsistence Hydrologic Links sedimentation Terrestrial Links animal and plant species (habitat, local population viability); erosion (soil protection); fire dynamics; soil productivity	**Description** small pieces of dead plant material on the surface of the soil, generally less than three inches in diameter **Relevance** Cultural/Social Links lifestyles and lifeways; land use and settlement patterns; social organizations; economics and subsistence Terrestrial Links gene flow (considerations for species with small territories or ranges)	**Description** small pieces of dead plant material on the surface of the soil, generally less than three inches in diameter **Relevance** Cultural/Social Links lifestyles and lifeways; land use and settlement patterns; social organizations; economics and subsistence

Matrix of Key Ecosystem Elements - Terrestrial Hierarchy

Ecosystem Element	Land Unit	Landscape	Subregion	Ecoregion
Organic Debris-Fine Organic Matter (continued)	**Affected by** Atmospheric Links climate (plant growth conditions, wind dispersal) Cultural/Social Links lifestyles and lifeways; economics and subsistence Hydrologic Links riparian plants Terrestrial Links fire behavior; plant species; soil productivity; windthrow and storm damage **Environmental Indicators** tons/acre and distribution (horizontal and vertical) by size class (fine fuels); percent effective ground cover (for use with EHR model)	**Affected by** Atmospheric Links climate (plant growth conditions) Cultural/Social Links all cultural/social elements Hydrologic Links riparian plants Terrestrial Links fire behavior; plant species; soil productivity; windthrow and storm damage **Environmental Indicators** tons/acre and distribution (horizontal and vertical) by size class (fine fuels); cumulative watershed analysis	**Affected by** Atmospheric Links climate (growing season) Cultural/Social Links all cultural/social elements Hydrologic Links riparian plants Terrestrial Links fire regimes; plant species **Environmental Indicators** habitat composition and structure (recruitment potential); soil productivity; rate of top soil formation	**Affected by** Atmospheric Links climate (growing season) Cultural/Social Links all cultural/social elements Hydrologic Links riparian plants Terrestrial Links fire regimes; plant species **Environmental Indicators** habitat composition and structure (recruitment potential); rate of top soil formation
Pathogens and Disease **(Process)**	**Description** pathogens and disease can weaken or kill individuals or groups of animals and plants with resultant changes in the ecosystem	**Description** pathogens and disease can weaken or kill individuals or groups of animals and plants with resultant changes in the ecosystem	**Description** pathogens and disease can weaken or kill individuals or groups of animals and plants with resultant changes in the ecosystem	**Description** pathogens and disease can weaken or kill groups of animals and plants with resultant changes in the ecosystem function

Matrix of Key Ecosystem Elements - Terrestrial Hierarchy

Ecosystem Element	Land Unit	Landscape	Subregion	Ecoregion
Pathogens and Disease (continued)	**Relevance** Hydrologic Links animal and plant species (vigor, composition, structure, individual and subpopulation stability and resilience); food web; organic debris Terrestrial Links animal and plant species (vigor, composition, structure, individual and subpopulation stability and resilience); fire behavior; food web; organic debris **Affected by** Hydrologic Links animal and plant species Terrestrial Links animal and plant species (vigor, composition); fire regimes	**Relevance** Cultural/Social Links land use and settlement patterns; population characteristics; economics and subsistence; invention and diffusion Hydrologic Links animal and plant species (vigor, composition, structure, population stability and resilience); food web; organic debris Terrestrial Links animal species (vigor, composition, structure, population stability and resilience); fire dynamics; organic debris; vegetation mosaic **Affected by** Cultural/Social Links attitudes, beliefs, and values; land use and settlement patterns; social organization; population characteristics; economics and subsistence; material culture; invention and diffusion	**Relevance** Cultural/Social Links land use and settlement patterns; population characteristics; economics and subsistence; invention and diffusion Hydrologic Links animal and plant species (habitat connectivity, gene flow for species specific pathogens and disease); food web Terrestrial Links animal and plant species (habitat connectivity, gene flow for species specific pathogens and disease); food web; vegetation mosaic **Affected by** Cultural/Social Links attitudes, beliefs, and values; land use and settlement patterns; social organization; population characteristics; economics and subsistence; material culture; invention and diffusion	**Relevance** Cultural/Social Links land use and settlement patterns; population characteristics; economics and subsistence; invention and diffusion Hydrologic Links animal and plant species (gene flow for species specific pathogens and disease) Terrestrial Links animal and plant species (gene flow for species specific pathogens and disease); vegetation mosaic **Affected by** Cultural/Social Links attitudes, beliefs, and values; land use and settlement patterns; social organization; population characteristics; economics and subsistence; material culture; invention and diffusion

Matrix of Key Ecosystem Elements - Terrestrial Hierarchy

Ecosystem Element	Land Unit	Landscape	Subregion	Ecoregion
Pathogens and Disease (continued)	**Environmental Indicators** outbreak severity, size, distribution, and species affected	Hydrologic Links animal and plant species Terrestrial Links animal and plant species (vigor, composition); fire regimes; vegetation mosaic **Environmental Indicators** outbreak severity, size, distribution, and species affected	Terrestrial Links vegetation mosaic; fire regimes; topography **Environmental Indicators** outbreak severity, size, distribution, species affected, and return rate	Terrestrial Links vegetation mosaic; fire regimes; topography **Environmental Indicators** temporal and spatial occurrence pattern
Plant Species **(Component)**	**Description** individuals, ramets, small populations, genets **Relevance** Cultural/Social Links all cultural\social elements Hydrologic Links channel morphology (stream habitat structure); nutrient pathways; organic debris Terrestrial Links animal species (occurrence); fire behavior; nutrient cycles; organic debris; soil productivity	**Description** populations **Relevance** Cultural/Social Links all cultural\social elements Hydrologic Links channel morphology (stream habitat structure); organic debris; nutrient pathways; sediment Terrestrial Links animal species (occurrence, distribution); fire dynamics; organic debris (soil cover);	**Description** entire ranges of subspecies or species **Relevance** Cultural/Social Links all cultural\social elements Terrestrial Links animal species (distribution); fire regimes; vegetation mosaic (pattern, distribution)	**Description** species and subspecies ranges **Relevance** Cultural/Social Links all cultural\social elements Terrestrial Links animal species (distribution); vegetation mosaic (pattern, distribution)

Matrix of Key Ecosystem Elements - Terrestrial Hierarchy

Ecosystem Element	Land Unit	Landscape	Subregion	Ecoregion
Plant Species (continued)		<u>Terrestrial Links</u> (continued) nutrient cycling; soil productivity (protection); vegetation mosaic (pattern, distribution)		
	Affected by <u>Atmospheric Links</u> climate	**Affected by** <u>Atmospheric Links</u> climate	**Affected by** <u>Atmospheric Links</u> climate	**Affected by** <u>Atmospheric Links</u> climate
	<u>Cultural/Social Links</u> all cultural\social elements	<u>Cultural/Social Links</u> all cultural\social elements	<u>Cultural/Social Links</u> all cultural\social elements	<u>Cultural/Social Links</u> all cultural\social elements
	<u>Hydrologic Links</u> flooding	<u>Hydrologic Links</u> flooding; nutrient pathways	<u>Hydrologic Links</u> flooding	<u>Hydrologic Links</u> flooding
	<u>Terrestrial Links</u> animal species (occurrence, competition —including allelopathy); fire behavior; insect infestation; nutrient cycles; organic debris; pathogens and disease; soil productivity	<u>Terrestrial Links</u> animal species (occurrence, distribution); fire dynamics; insect infestation; nutrient cycles; organic debris; pathogens and disease; soil productivity	<u>Terrestrial Links</u> animal species (distribution); fire regimes	<u>Terrestrial Links</u> animal species (distribution); fire regimes

Matrix of Key Ecosystem Elements - Terrestrial Hierarchy

Ecosystem Element	Land Unit	Landscape	Subregion	Ecoregion
Plant Species (continued)	**Environmental Indicators** presence/absence; species cover, frequency, volume, basal area, density, leaf area index; demographics (fecundity, age class); extent of native local germplasm; extent and distribution of local gene pools	**Environmental Indicators** species occurrence, cover, frequency, volume, basal area, distribution, and fragmentation; demographics; extent and distribution of native local gene pools; extent of native local germplasm	**Environmental Indicators** species occurrence, cover, distribution, fragmentation, and demographics; extent and distribution of genes, races, subspecies, or ecotypes	**Environmental Indicators** species cover, distribution, fragmentation, and demographics; extent and distribution of races, subspecies, or ecotypes
Soil Hydrology **(Process)**	**Description** inherent capacity of a soil to intake, retain, and transmit water **Relevance** <u>Cultural/Social Links</u> lifestyles and lifeways; land use and settlement patterns; social organization; population characteristics; economics and subsistence <u>Hydrologic Links</u> nutrient pathways; plant species; runoff intensity and duration (flood frequency, timing)	**Description** inherent capacity of a soil to intake, retain, and transmit water **Relevance** <u>Cultural/Social Links</u> lifestyles and lifeways; land use and settlement patterns; social organization; population characteristics; economics and subsistence <u>Hydrologic Links</u> nutrient pathways; plant species; runoff intensity and duration (flood frequency, timing); water quality	**Description** inherent capacity of a soil to intake, retain, and transmit water **Relevance** <u>Cultural/Social Links</u> lifestyles and lifeways; land use and settlement patterns; social organization; population characteristics; economics and subsistence <u>Hydrologic Links</u> plant species; water quality <u>Terrestrial Links</u> plant species (productivity); nutrient cycles; vegetation mosaic (cover by species)	**Description** inherent capacity of a soil to intake, retain, and transmit water **Relevance** <u>Cultural/Social Links</u> lifestyles and lifeways; land use and settlement patterns; social organization; population characteristics; economics and subsistence <u>Hydrologic Links</u> plant species; water quality <u>Terrestrial Links</u> plant species; nutrient cycles; vegetation mosaic (cover by species

Matrix of Key Ecosystem Elements - Terrestrial Hierarchy

Ecosystem Element	Land Unit	Landscape	Subregion	Ecoregion
Soil Hydrology (continued)	Terrestrial Links plant species (productivity); nutrient cycles; soil characteristics (water holding capacity; soil air/water movement, infiltration)	Terrestrial Links plant species (productivity); nutrient cycles; organic debris (large woody); soil characteristics (water holding capacity; soil air/water movement, infiltration); vegetation mosaic (cover by species)		
	Affected by Atmospheric Links climate	**Affected by** Atmospheric Links climate	**Affected by** Atmospheric Links climate	**Affected by** Atmospheric Links climate
	Cultural/Social Links land use and settlement patterns; economics and subsistence	Cultural/Social Links lifestyles and lifeways; land use and settlement patterns; social organization; population characteristics; economics and subsistence; material culture; invention and diffusion	Cultural/Social Links lifestyles and lifeways; land use and settlement patterns; social organization; population characteristics; economics and subsistence; material culture; invention and diffusion	Cultural/Social Links lifestyles and lifeways; land use and settlement patterns; social organization; population characteristics; economics and subsistence; material culture; invention and diffusion
	Hydrologic Links hydrologic cycle, plant species	Hydrologic Links hydrologic cycle, plant species	Hydrologic Links hydrologic cycle	Hydrologic Links hydrologic cycle
	Terrestrial Links animal and plant species (micro and macro); erosion; organic debris (fine organic matter); soil characteristics (physical and chemical properties)	Terrestrial Links animal and plant species (micro and macro); erosion; organic debris (fine organic matter); soil characteristics (physical and chemical properties); vegetation mosaic (cover by species)	Terrestrial Links erosion; vegetation mosaic (cover by species)	Terrestrial Links erosion; vegetation mosaic

Matrix of Key Ecosystem Elements - Terrestrial Hierarchy

Ecosystem Element	Land Unit	Landscape	Subregion	Ecoregion
Soil Hydrology (continued)	**Environmental Indicators** natural soil drainage class; soil characteristics (bulk density, clay layers, compaction, particle size distribution, pore space); vegetation type and water requirements	**Environmental Indicators** natural soil drainage class; soil characteristics (bulk density, clay layers, compaction, particle size distribution, pore space); vegetation type and water requirements	**Environmental Indicators** individual or groups of natural soil drainage classes; vegetation mosaic	**Environmental Indicators** groups of natural soil drainage classes; vegetation mosaic
Soil Productivity **(Component, Structure, & Process)**	**Description** biomass support, as differentiated by quantity, diversity, and other characteristics of the biological community **Relevance** <u>Cultural/Social Links</u> lifestyles and lifeways; land use and settlement patterns; social organization; population characteristics; economics and subsistence <u>Hydrologic Links</u> nutrient pathways; plant species; runoff intensity and duration (flood frequency, timing)	**Description** biomass support, as differentiated by quantity, diversity, and other characteristics of the biological community **Relevance** <u>Cultural/Social Links</u> lifestyles and lifeways; land use and settlement patterns; social organization; population characteristics; economics and subsistence <u>Hydrologic Links</u> nutrient pathways; plant species; runoff intensity and duration (flood frequency, timing); water quality	**Description** biomass support, as differentiated by quantity, diversity, and other characteristics of the biological community **Relevance** <u>Cultural/Social Links</u> lifestyles and lifeways; land use and settlement patterns; social organization; population characteristics; economics and subsistence <u>Hydrologic Links</u> plant species; water quality <u>Terrestrial Links</u> plant species (productivity); nutrient cycles; vegetation mosaic (cover by species)	**Description** biomass support, as differentiated by quantity, diversity, and other characteristics of the biological community **Relevance** <u>Cultural/Social Links</u> lifestyles and lifeways; land use and settlement patterns; social organization; population characteristics; economics and subsistence <u>Hydrologic Links</u> plant species; water quality <u>Terrestrial Links</u> plant species; nutrient cycles; vegetation mosaic (cover by species)

Matrix of Key Ecosystem Elements - Terrestrial Hierarchy

Ecosystem Element	Land Unit	Landscape	Subregion	Ecoregion
Soil Productivity (continued)	Terrestrial Links plant species (productivity); nutrient cycles; organic debris (large woody); soil characteristics (water holding capacity; soil air/water movement, infiltration); vegetation mosaic (cover by species)	Terrestrial Links plant species (productivity); nutrient cycles; organic debris (large woody); soil characteristics (water holding capacity; soil air/water movement, infiltration); vegetation mosaic (cover by species)		
	Affected by Atmospheric Links climate	**Affected by** Atmospheric Links climate	**Affected by** Atmospheric Links climate	**Affected by** Atmospheric Links climate
	Cultural/Social Links land use and settlement patterns; economics and subsistence	Cultural/Social Links lifestyles and lifeways; land use and settlement patterns; social organization; population characteristics; economics and subsistence; material culture; invention and diffusion	Cultural/Social Links lifestyles and lifeways; land use and settlement patterns; social organization; population characteristics; economics and subsistence; material culture; invention and diffusion	Cultural/Social Links lifestyles and lifeways; land use and settlement patterns; social organization; population characteristics; economics and subsistence; material culture; invention and diffusion
	Hydrologic Links hydrologic cycle, plant species	Hydrologic Links hydrologic cycle, plant species	Hydrologic Links hydrologic cycle	Hydrologic Links hydrologic cycle
	Terrestrial Links animal and plant species (micro and macro); erosion; fire; nutrient cycles; organic debris (fine organic matter); soil characteristics (physical and chemical properties)	Terrestrial Links animal and plant species (micro and macro); erosion; fire; geology; nutrient cycles; organic debris (fine organic matter); soil characteristics (physical and chemical properties); vegetation mosaic (cover by species)	Terrestrial Links erosion; fire; geology; vegetation mosaic (cover by species)	Terrestrial Links erosion; fire; geology; vegetation mosaic

Matrix of Key Ecosystem Elements - Terrestrial Hierarchy

Ecosystem Element	Land Unit	Landscape	Subregion	Ecoregion
Soil Productivity (continued)	**Environmental Indicators** percent effective ground cover; soil organic matter content; soil bulk density; chemical and physical attributes; biologic activity	**Environmental Indicators** cumulative watershed effects analysis; site indices; vegetation type and production; potential natural vegetation	**Environmental Indicators** multiple cumulative watershed effects analyses; existing vegetation mosaic and production; potential natural vegetation	**Environmental Indicators** multiple cumulative watershed effects analyses; existing vegetation mosaic vs potential natural vegetation
Vegetation Mosaic **(Structure)**	**Description** vegetation patch(s) identified by similar composition and structure, each defined as a "series" **Relevance** <u>Cultural/Social Links</u> all cultural\social elements <u>Hydrologic Links</u> hydrologic cycle <u>Terrestrial Links</u> animal and plant species (amount of habitat for individuals, fragmentation effects, species composition); erosion	**Description** vegetation patches identified by similar composition and structure, each defined as a "series" **Relevance** <u>Cultural/Social Links</u> all cultural\social elements <u>Hydrologic Links</u> hydrologic cycle <u>Terrestrial Links</u> animal and plant species (amount and arrangement of habitat for individual or populations, fragmentation effects, connectivity, population structure and dynamics); erosion	**Description** an aggregation of similar series to simplify complex areas by creating larger patches **Relevance** <u>Cultural/Social Links</u> all cultural\social elements <u>Hydrologic Links</u> hydrologic cycle <u>Terrestrial Links</u> animal and plant species (amount and arrangement of habitat for populations, fragmentation effects, connectivity, population structure and dynamics)	**Description** an aggregation of similar series to simplify complex areas by creating larger patches **Relevance** <u>Cultural/Social Links</u> all cultural\social elements <u>Hydrologic Links</u> hydrologic cycle <u>Terrestrial Links</u> animal and plant species (amount and arrangement of habitat for populations, fragmentation effects, connectivity, population structure and dynamics)

Matrix of Key Ecosystem Elements - Terrestrial Hierarchy

Ecosystem Element	Land Unit	Landscape	Subregion	Ecoregion
Vegetation Mosaic (continued)	**Affected by** Atmospheric Links climate Cultural/Social Links all cultural/social elements Terrestrial Links erosion; fire regimes; insect infestations; pathogens and disease; plant species (structural heterogeneity—gap dynamics, location); soil productivity **Environmental Indicators** suitable habitat area (including cover by species); patch size; shape indices; landscape location; pattern analysis (re: gaps); nearest neighbor analysis	**Affected by** Atmospheric Links climate Cultural/Social Links all cultural/social elements Terrestrial Links erosion; fire regimes; insect infestations; pathogens and disease; plant species; soil productivity; topography **Environmental Indicators** total habitat area; suitable habitat area; habitat arrangement; frequency of patch sizes; shape indices; connectivity; fragmentation; subregion location; pattern analysis; frequency of occurrence across the range of potential substrates (re: plant communities)	**Affected by** Atmospheric Links climate Cultural/Social Links all cultural/social elements Terrestrial Links fire regimes; insect infestations; pathogens and disease; plant species; soil types; topography **Environmental Indicators** total habitat area; suitable habitat area; habitat arrangement; frequency of patch sizes; fragmentation; connectivity; ecoregion location; pattern analysis; frequency of occurrence across the range of potential substrates (re: plant communities)	**Affected by** Atmospheric Links climate Cultural/Social Links all cultural/social elements Terrestrial Links fire regimes; insect infestations; pathogens and disease; plant species; soil series; topographic variation **Environmental Indicators** total habitat area; suitable habitat area; habitat arrangement; fragmentation; connectivity; pattern analysis; frequency of occurrence across the range of potential substrates (re: plant communities)

Appendix B

Example

Table of Contents

Appendix B

Example

Science, like everything else, has its borderland
from which the brain can easily slip off into chaos.

Marie Corelli

This example uses an extensive list of Key Ecosystem Elements and Environmental Indicators to illustrate how biological, physical, and cultural/ social analyses might be employed, and is designed to illustrate techniques of deriving Reference Variability. The number of indicators involved would likely be less, due to budgetary constraints and driving issues focusing the analysis.

It is often easier to discuss analysis concepts and processes than to practice them. An example is provided here to help illustrate how the concepts, tools, and techniques described in the Conceptual Framework can be used. It does not illustrate all the steps in the planning and analysis process. Only a few of the Indicators discussed are taken all the way through an analysis process to arrive at a Reference Variability and Recommended Management Variability. This example's analysis area is fictitious, and therefore, some combinations of features and values may never actually coexist.

The following steps in deriving Reference Variability and Recommended Management Variability are discussed:

- characterizing the dominant features of the area,
- identifying Key Ecosystem Elements and Environmental Indicators, and
- arriving at Reference Variability and Recommended Management Variability for selected Environmental Indicators.

Dominant Features

The dominant features of the area provide a basis for choosing Elements and Indicators to be analyzed. The analysis area consists of dominant features described below.

Physical Description

The area of interest includes three watersheds, and elevation ranges from 4,000 - 9,000 feet. Precipitation ranges from 25-35 inches per year, 2/3 snow and 1/3 rain. The geology of the area is primarily granitic batholith with a highly altered volcanic intrusion. One soil type dominates [Cagwin soils (series), Typic Cryopsamments (family), Entisols (order)]; it has a moderate to high erosion hazard rating (i.e., high sedimentation potential) and is excessively well drained.
The entire state is in the middle of a 30 year drought cycle, and ecological and social ramifications are beginning to surface, such as water shortages and increased tree mortality. Stream flow regimes are not altered by water diversions within the watersheds.

Biological Description

The area is occupied by forested and meadow vegetation series, including: Jeffrey Pine (20K ac), Mixed Conifer (30K ac), White fir (30K ac), Red Fir

(18K ac), and bear grass/sedge meadows and sagebrush flats (2K ac). Aquatic biota are highly diverse, but are declining in integrity in a number of ways. The primary points of interest consist of: one species of threatened fish, one sensitive plant species, water quality, declining amphibian populations, and declining native fish populations. Terrestrial biota have slightly declined in diversity over the last 50 years. The terrestrial concerns are two species of sensitive plants, three species of sensitive wildlife species, one threatened wildlife species, and low populations of top predators.

Cultural/Social Description

The area has had a diverse cultural/social character for the last 7,000 years. Initial occupation (during the middle Holocene) was limited, but populations increased through time. By 500 years ago, the area was inhabited by 4 major tribal groups, the Maidu, Miwok, Paiute, and Washo, with a maximum population of about 2,000. Some early exploration by Europeans occurred during the 1830s, but the major influx of Euroamericans took place during the Gold Rush following 1849. The early mining activity was followed by Chinese groups reworking many of the same areas. During the 1890s, Basque sheep herders used the mountain meadow areas. Since this time, the area has experienced scattered occupation and use, including numerous Italian-Swiss dairy farms in the high meadow areas. After the turn of the century, Forest Service management emphasized timber harvest.

Current uses include the following: bear hunting, migratory bird watching, wood products, bear grass gathering for basket making, hiking, camping, fishing, cross-country skiing, sheep and cattle grazing, and timber harvest. There are two rancherias, Miwok and Maidu, and members of the four original tribal groups live scattered throughout the area. Descendants of the Basque and Italian-Swiss live in the area and still practice traditional lifeways. Most Chinese have moved into the adjacent urban areas. A recent influx of urbanites and retirees from mixed socio-cultural backgrounds has moved into the area in the last two decades. Four parcels of private land exist within the area, which are owned by the Empress Timber Co. The area is within 30 minutes by road of a community of 100,000 people.

Elements and Indicators

Table B-1 lists the Key Ecosystem Elements and their associated Environmental Indicators selected for the area. They represent a combination of coarse-filter, fine-filter, open-system, and closed-system Elements from each of the four ecosystem hierarchies. The list resulted from a very thorough evaluation of the area, with many Elements and Indicators chosen for analysis and consideration in future management. Not all analyses will yield such a lengthy list of Environmental Indicators.

Table B-1. Key Ecosystem Elements and their Environmental Indicators. CF = coarse-filter, FF = fine-filter, OS = open-system, CS = closed-system, EH = ecosystem hierarchy (T = terrestrial, H = hydrologic, A = atmospheric, C = cultural/social).

Element	Environmental Indicator	CF	FF	OS	CS	EH
Terrestrial Animal Species (Component)	taxonomic diversity	X				T
	trophic diversity	X				T
	proportion of native species present	X				T
	population abundance and distribution of individuals and habitat for:					T
	bear (popular game species, upland)	X	X			
	american marten (top predator, sensitive species, high mobility, upland and riparian)	X	X			
	long-toed salamander (sensitive species, limited mobility, riparian)	X	X			
	red tree vole (sensitive species, moderate mobility, upland)	X	X			
	Wintu sideband (threatened mollusc species, limited mobility, riparian)	X	X			
	White-headed woodpecker (high elevation, cavity nester)	X				
	Ensatina salamander	X				
Terrestrial Plant Species (Component)	taxonomic diversity					T
	proportion of native species present					T
	population distribution and demographics:					T
	pleasant valley mariposa (sensitive, fire affected and silviculture)	X	X			
	bolander clover (grazing effects, sensitive)	X	X			
	bear grass (cultural uses)		X		X	T/C
Vegetation Mosaic (Structure)	series by seral stage	X				T
	fragmentation	X				T
	series complexes	X				T
	refugia size and location	X				T
Woody Debris (Component and Structure)	density and distribution by size class for snags, logs and fine material	X				T
	recruitment potential by size class for snags, logs and fine material	X				T
Fire (Process)	return rate by vegetation series	X				T/H
	severity characteristics by vegetation series	X				T/H
	timing by vegetation series	X				T/H
Water (Component and Structure)	**vegetative cover within watersheds** (type and amount)	X				H
	streamflow hydrograph (timing and amount)	X				H
	stream temperature	X				H/C
	bacterial levels	X				H/C

Table B-1. continued

Element	Environmental Indicator	CF	FF	OS	CS	EH
Sediment (Component and Structure)	V*	X				H
	RASI	X				H
	D50	X				H
Channel Morphology (Component and Structure)	channel type abundance and distribution	X				H
	habitat type abundance and distribution	X				H
	pool/riffle ratio	X				H
Aquatic Animal Species (Component)	Mountain yellow-legged frog (sensitive species)	X	X			H
	population demographics of Lahonton cuthroat trout (threatened species)		X			H
	percentage of native fish (number)	X				H
	percentage of native vertebrate species	X				H
	total fish abundance	X				H
	total fish species	X				H
	juvenile trout abundance	X				H
	number and type of aquatic insect families	X				H
	number and distribution of frog and toad species	X				H
Nutrient Cycles (Process)	woody debris within stream channel	X				H
	macroinvertebrate drift within stream	X				H
	fish carcasses within stream	X				H
	quantity and composition of leaf fall	X				H
Riparian/Aquatic Vegetation (Component)	series by seral stage acreage and distribution	X				H
	canopy closure	X				T/H
	shading	X				T/H
	serrate leaf louisia (stem succulent from riparian corridors affected by flow and mist, sensitive)	X	X			T/H
Erosion (Process)	frequency, distribution, and sediment contribution of erosional areas	X				T/H
Sulfur Dioxide and Particulate Matter (Component)	lichen species distribution and abundance	X	X			A/T
	sulfur dioxide concentrations	X				A
	particulate matter concentrations	X				A
Attitudes, Beliefs and Values (Component)	traditional cultural values of the area			X	X	C
	community concerns and attitudes about management of the area			X	X	C
Lifestyles and Lifeways (Component)	level of local fuelwood uses				X	C
	bear grass and sedge quantity, quality, access, and harvest experience				X	C/T
	grazing use			X	X	C
	recreation use (userdays) for hiking, skiing, bird watching, camping, and fishing			X	X	C
	timber harvest			X	X	C/T

Table B-1. continued

Element	Environmental Indicator	CF	FF	OS	CS	EH
Land Use and Settlement Pattern (Structure)	resource procurement sites			X	X	C
	ownership patterns and trends			X		C
	road density by type			X	X	C
Population Characteristics (Structure)	population demographics (density, gender, age structure, race)			X	X	C
	population growth rate			X		C
Economics and Subsistence (Process)	proportion of local community dependent on forest products and uses (by type)			X	X	C
	income levels per capita in local community			X		C
	seasonal subsistence cycle (prehistoric)			X	X	C
Material Culture (Component and Structure)	types, condition and use of structures			X		C
	artifacts representing various cultures and activities			X		C
Invention and Diffusion (Process)	change in cultural uses of bear grass				X	C
	technological advancement in timber removal, fishing techniques, and vegetation control			X		C

Reference Variability and Recommended Management Variability

The following discussions represent some of the steps required to derive Reference Variability and Recommended Management Variability for some of the Environmental Indicators. Five Elements (and their associated Environmental Indicators) are discussed in greater detail below: sediment, vegetation mosaic, terrestrial animal species, aquatic animal species, and lifestyles and lifeways.

Sediment Element

Historical data do not exist for most Environmental Indicators of aquatic conditions. Deriving Reference Variability and Recommended Management Variability values for Environmental Indicators of the sediment Element in this example requires relying on Reference Areas as proxies to historical conditions. Reference Areas in this example consist of subwatersheds within each of the three main watersheds. In addition, an effort is made to validate the usefulness of the chosen Environmental Indicators.

The detailed information presented here in the derivation of Reference Variabilities and Recommended Management Variabilities for the sediment Environmental Indicators are based on an actual field study conducted by the North Coast Water Quality Board (Knopp 1993).

Subwatersheds are considered suitable reference areas if their disturbance regimes are relatively unaltered. Six subwatersheds are chosen for sampling. The subwatersheds chosen as Reference Areas include subwatersheds with no previous management activities and subwatersheds with no management activity for at least the past 40 years.

Reference Areas influenced by management 40 or more years in the past are assumed to be proxies for unmanaged areas that have recently experienced a disturbance event characteristic of what might occur in an unaltered disturbance regime.

Historically managed Reference Areas are seen as a valuable addition to the Reference Areas because the unmanaged areas had not experienced any disturbances for a long period of time and may not represent the full range of potential ecological conditions that would exist under unaltered disturbance regimes. Reference Areas have limits as proxies for historic data; the primary limitation being that the array of areas suitable as Reference Areas have probably all experienced disturbance at the same time, so they may not represent the full range of conditions (i.e., recent disturbance vs long period lacking disturbance). Therefore, it made sense to include Reference Areas with past disturbance to better understand the effects of past disturbance on Environmental Indicators, and to make the Reference Variability as representative of the full range of potential values as possible. The Reference areas used still do not reflect conditions that would result following a large disturbance.

Environmental Indicators need to be validated at some point in the implementation process. The most valuable Environmental Indicators are those that are sensitive to changes in environmental conditions. In order to validate the Environmental Indicators for the sediment Element, recently managed subwatersheds (moderate and high levels of management) are also sampled to assess the sensitivity of the Indicators to environmental change.

Seven Indicators are identified: V*, RASI, D50, Wood Volume, Wood Cover, Pool Volume, and Substrate Change (associated with large wood). The relative performance (i.e., sensitivity) of the Indicators is used to validate the utility of the three Environmental Indicators initially chosen for the assessment. The seven Indicators are defined below:

- *V** represents the proportion of fine sediment occupying the total scoured volume of a pool.
- *RASI (Riffle Armor Stability Index)* is the percent of a riffle's cumulative surface particle size distribution that is smaller than or equal to the largest particles annually transported by high flows.
- *D50* is the medium particle size found in streambed substrate. Many other variables can be used but monetary limitations may restrict selection to physical parameters.
- *Wood Volume* is measured within the active channel and reflects the total volume of wood.
- *Wood Cover* is measured as the area of a shadow cast on the stream bed.
- *Pool Volume* is measured by estimating an average depth for a pool and multiplying it by the pool's surface area.
- *Substrate Change* reflects the surface area of deposited or scour-exposed gravels. Substrate is measured within the active channel.

To isolate variance due to geology and channel morphology, sampling locations within subwatersheds are limited to a selected geology and channel type: Granitic batholith formation; channels exhibiting small cobble substrates; and slopes of 1-4%. Sixty reaches within the six subwatersheds, each 1000 meters long, are sampled for V*, RASI and D50.

Additionally, selection criteria for pools and riffles are established to restrict sampling locations to similar morphological features. Six pools per 1000 meter reach are sampled for V* and pool volume, three riffles for RASI, and the entire reach for wood volume, wood cover, and substrate change.

The results of sampling yield three important pieces of information: 1) of the seven Indicators used, V*, RASI, and D50 (the three Environmental Indicators originally selected) had the greatest sensitivity to disturbance and are useful for tracking environmental change; 2) two types of Reference Areas (unmanaged and managed over 40 years prior) differ in the variability observed in all Indicators; and 3) variation in values across reference and managed areas provides information useful for determining Recommended Management Variability. Variation in the values of the three Environmental Indicators across the four types of areas sampled are discussed below.

Riffle Armor Stability Index

Riffle Armor Stability Index (RASI) values show a positive correlation with increasing levels of upslope management. This trend indicates that it is a sensitive environmental Indicator (Table B-2). Significant differences ($p < 0.05$) are observed between Reference Areas and areas with recent management. Even the two categories of Reference Areas are significantly different.

The full range of Reference Variability values for RASI is represented by the minimum and maximum values across all Reference Areas (24.10 - 80.0) (Table B-2), since it appears that unmanaged areas have an unrepresentative restricted range of values. Recently managed areas had a reduced range of values (similar range of values as historically managed reaches), and the higher values were outside Reference Variability.

Using professional judgement, Recommended Management Variability for RASI may be the entire range of values for the reference areas, since the upper bound is what is of concern (i.e., high sedimentation), and any management appears to raise RASI values. Note that for this and all other sediment Environmental Indicators, the spatial and temporal distribution of the Reference Variability and Recommended Management Variability values is not addressed. Spatial arrangement of values should be considered whenever possible, as well as how these values vary over time within and among areas. The distribution of these values is important to note because it appears that management eliminates the occurrence of low values and narrows the distribution.

Finally, RASI is a coarse-filter Indicator, meaning that its status should be evaluated along with other coarse-filter and open-system Indicators to determine the overall status of the ecosystem. Monitoring RASI (and other coarse-filter Indicators) over time as actions are taken to achieve desired condition will provide information on how the ecosystem is changing in response to management and help validate predicted responses.

Table B-2. Riffle Armor Stability Index values by management category. RASI represents the cumulative percent of the riffle substrates that are smaller or equal size to the largest mobile particle on the riffle surface. s.d. = standard deviation.

	Reference Areas			Recently Managed	
RASI	Unmanaged	Historical Management	All Reference Areas	Moderate Management	High Management
mean	52.61	69.81	58.34	72.38	77.02
s.d.	12.89	9.14	14.20	11.26	11.34
minimum	24.10	53.57	24.10	53.93	55.40
maximum	75.00	80.00	80.00	92.10	97.20
N	12	6	18	21	21

D50

A clear trend of decreasing particle size in the riffles was evident with increasing upslope disturbance indicating that D50 is a sensitive Environmental Indicator for evaluating sedimentation in relation to disturbance levels (Table B-3). Historically managed reaches were not different from moderately or highly managed reaches, although both appear to exhibit smaller particle sizes. The unmanaged reaches were significantly different ($p < 0.05$) from each of the other types of reaches. Moderately managed reaches are not significantly different from highly managed reaches.

Reference Variability is best approximated by minimum and maximum values within unmanaged reaches (37.43 - 183.13) since they express the greatest range of values observed in Reference Areas (Table B-3). Historically managed reaches had much lower maximum values of D50, resulting in a much reduced range (55 point spread versus 145 point spread for unmanaged reaches). Recently managed reaches had approximately the same upper limits as historically managed reaches, but the minimum values were outside Reference Variability.

Recommended Management Variability for this Indicator requires looking a little closer at the data. The minimum value for Recommended Management Variability is probably legitimately the minimum value of unmanaged reaches. However, Recommended Management Variability should probably be some value lower than the maximum for unmanaged reaches. The standard deviation for unmanaged reaches compared to other reach types indicates that the maximum value for unmanaged reaches may have been an outlier. A closer look at the unmanaged reaches might suggest what the upper limit for Recommended Management Variability should be. It would also be informative to know what conditions contributed to creating such low D50 values in managed reaches. Based on professional judgement, Recommended Management Variability would equal Reference Variability.

V*

V* measurements showed a trend of increasing accumulations of fine sediments with increasing upslope disturbance indicating that V* is affected by upslope disturbance and is a sensitive Environmental Indicator for evaluating the effects of

Table B-3. D50s by category. D50s represent pebble count data collected to characterize RASI values in riffles. Values represent median particle sizes in millimeters. s.d. = standard deviation.

	Reference Areas			Recently Managed	
D50 of Riffle	Unmanaged	Historical Management	All Reference Areas	Moderate Management	High Management
mean	80.66	47.07	69.46	41.46	37.61
s.d.	42.17	6.97	37.82	12.20	13.20
minimum	37.43	38.43	37.43	17.03	10.20
maximum	183.13	57.70	183.13	61.93	60.83
N	12	6	18	21	21

disturbance on sedimentation (Table B-4). Unmanaged and historically managed reaches are significantly different ($p < 0.05$) from each other. All Reference Areas combined is also significantly different from both of the managed reaches.

Reference Variability values are best represented by the minimum and maximum values across all Reference Areas (0.07-0.45), since it appears the unmanaged areas potentially have an artificially restricted range of values because of altered and reduced disturbance regimes (Table B-4). Managed areas have an expanded range of values, with lower limits coincident with Reference Areas, but upper values outside Reference Variability.

In this case, it does not follow that Recommended Management Variability would be a reduced range of values, since disturbance tends to increase the upper bounds of the range. Recommended Management Variability is probably the same as Reference Variability in this situation.

Vegetation Mosaic Element

This example describes the derivation of Reference Variability using the past 200 years as the reference period. The Environmental Indicators selected for the vegetation mosaic Element are: vegetation series by seral stages, fragmentation, and refugia size and location (Table B-1). Vegetation series by seral stage was chosen for elaboration here. The other Indicators are not discussed. The data values for this example are extracted from Jimerson (1993), but some aspects of the example have been rearranged to where the values no longer represent a specific situation.

Vegetation series is selected as an Environmental Indicator because vegetation series represent a fixed set of environmental conditions and they carry within them discrete disturbance regimes. The assumption is that maintaining representative proportions of various vegetation series would provide habitat for populations of many plant and animal species and therefore conserve biological diversity (Noss 1987; Hunter 1991).

Table B-4. V* values for each disturbance category. V* values represent the proportion of total scoured pool volume that is occupied by fine sediments. Proportions are shown in decimal form. s.d. = standard deviation.

	Reference Areas			Recently Managed	
V*	Unmanaged	Historical Management	All Reference Areas	Moderate Management	High Management
mean	0.07	0.12	0.10	0.20	0.18
s.d.	42.17	6.97	37.82	12.20	13.20
minimum	0.07	0.14	0.07	0.12	0.12
maximum	0.27	0.45	0.45	0.91	0.77
N	12	6	18	21	21

Vegetation is mapped on a combination of aerial photos and ortho quads. Ortho quad overlays were scanned into a geographic information system (e.g., the Region 5 Distributed Wildland Resource Information System - DWRIS). A data base is created that describes the map. The data base includes a description of each vegetation polygon (number, location, perimeter in feet, interior acres) series, seral stage, size class, canopy closure and acres.

The Jeffrey pine, mixed conifer, white fir and red fir series are selected as the primary series of interest because they make up a large proportion of the study area. To determine what the characteristics of the vegetation mosaic were over time in the past, vegetation is projected backwards in time to reconstruct the range of abundance of vegetation series by seral stage. Vegetative conditions are described between 1790 and 1990 at five points in time: 1790, 1840, 1890, 1940, and 1990. Data used to calculate vegetative conditions at these time frames are: current distribution of seral stages (for each series) in areas with a minimum of human influence, fire history in the general area (yielding information on the frequency and extent of stand replacing fires), and growth rates based on Dunning site classes 1A-3 and slope position. In addition, the assumption was made that fires occurring within the shrub/forb and pole seral stages are of a stand replacing nature, while only a proportion (based on the data mentioned above) of the fires in the mature and old-growth seral stages are stand replacing.

The current proportion of acres in each seral stage for each forest vegetation series is listed in Table B-5.

Using these proportions as a starting point, stands are "grown backwards" in five 50 year time steps. Considerations in growing vegetation backwards include variation in growth rates, and therefore ranges of stand ages within each seral stage, as a result of site productivity. In addition, the current condition of the series is differentially affected by management (i.e., timber harvesting and fire suppression). Finally, when the shrub/forb seral stage is reached, acres moving backward need to be placed into the seral stages from which they originated. Here they are partitioned into all the other seral stages based on the frequency of stand replacing fires within each seral stage.

Table B-5. Proportion of acres in each seral stage by vegetation series.

		Percent Return			
Seral Stage	**Age (years)**	**Jeffrey Pine**	**Mixed Conifer**	**White Fir**	**Red Fir**
Shrub/forb	0 - 40	8	10	12	13
Pole	41 - 70	7	9	10	12
Early Mature	71 - 110	6	8	9	11
Mid Mature	111 - 150	5	7	8	8
Late Mature	151 - 200	3	5	5	6
Old Growth	> 200	71	61	56	50
Total Acres (thousands)		20	30	30	18

Results of the series by seral stage frequency analysis between 1940 and 1990 indicates that two disturbance regimes were prevalent (Table B-6). Jeffrey pine and mixed conifer series had similar Reference Variability values for proportion in each seral stage. White fir and red fir series also had similar Reference Variability values, but differed from both the Jeffrey pine and mixed conifer series. This is probably due to similar species occurring in the paired series and hence they had similar physiological responses to disturbance.

Stand age decreases across the series (listed from low to high): Jeffrey pine, mixed conifer, white fir, red fir. This indicates an increase in stand replacing disturbance probably related to lightning induced wildfires that occur along the elevation gradient on which these series are oriented. The result of this increase in wildfire is reflected in the wider range of frequency by seral stage in the white fir and red fir series.

Table B-6. Reference Variability by vegetation series and seral stage from 1790-1990, compared to existing conditions.

Series	Seral Stage	Reference Variability (%)	Mean (%)	Existing Condition (%)
Jeffrey Pine	Shrub/forb	1 - 25	14	7
	Pole	6 - 20	11	18
	Early Mature	5 - 25	14	25
	Mid Mature	2 - 23	11	23
	Late Mature	2 - 12	8	2
	Old Mature	33 - 53	42	25
Mixed Conifer	Shrub/forb	2 - 25	14	7
	Pole	3 - 17	11	6
	Early Mature	5 - 24	15	19
	Mid Mature	2 - 29	12	29
	Late Mature	2 - 13	9	2
	Old Mature	32 - 45	40	37
White Fir	Shrub/forb	6 - 30	18	7
	Pole	8 - 25	13	8
	Early Mature	6 - 34	16	34
	Mid Mature	2 - 20	10	20
	Late Mature	1 - 11	6	1
	Old Mature	25 - 52	37	29
Red Fir	Shrub/forb	5 - 37	21	5
	Pole	9 - 30	16	11
	Early Mature	5 - 40	18	40
	Mid Mature	1 - 26	10	26
	Late Mature	1 - 7	4	1
	Old Mature	16 - 54	31	17

Variation in the proportions of each series in each seral stage over the five time periods analyzed between 1790 and 1990 (recently harvested stands were represented as old-growth) were used to derive the Reference Variability. All seral stages in all series are currently within Reference Variability with the exception of old-growth in the Jeffrey pine series. However, many of the current acreages are at the extreme values for the Reference Variability, and therefore additional analysis is needed to provide insights to how the system would respond to various management scenarios.

Values for Recommended Management Variability can be derived by looking more closely at what created the extreme values of the ranges and the status of disturbance regimes during the reference period to determine: 1) if extreme values are adequately represented in the Reference Variability; 2) what, if any, reduction in the range of values created as a result of management is prudent to sustain the system. At this point, a professional judgement could lead to the conclusion that Recommended Management Variability would coincide with Reference Variability.

The spatial and temporal distribution of these ranges is not discussed here. Spatial and temporal distribution is especially pertinent for the vegetation mosaic Element, since their Indicators such as fragmentation and refugia size and location, are entirely predicated on the spatial distribution of seral stages over time.

Terrestrial Animal Species Element

Four main Environmental Indicators were chosen for this Element (Table B-1). One Environmental Indicator, population distribution and abundance, consists of seven Indicator species. One Indicator, the ensatina (a salamander), will be elaborated on here.

Historic ensatina population sizes are difficult to estimate because this species is highly dependent on microhabitat conditions, for which historic data are not available. The ensatina requires > 10" diameter logs, 4-8 per acre, and soil needs to be friable. The number of individuals to maintain a viable population within the area is estimated to be 2000-3000 individuals.

Under unaltered disturbance regimes (i.e., frequent low intensity fires, insect killed trees), log size and abundance and other microclimatic conditions are assumed to be adequate within mid mature to old-growth seral stages of Jeffrey pine and mixed conifer vegetation series. Reference Variabilities for population levels can be estimated based on the Reference Variabilities for the suitable seral stages and vegetation series. The other series occur at too high an elevation for the ensatina. Therefore, Reference Variability for the ensatina is comprised of two components:

1) acreage of mid mature through old growth seral stage of Jeffrey pine and mixed conifer vegetation series; and
2) logs per acre (4-8 per acre over 10" diameter) within these vegetation series and seral stages.

Table B-7 lists the Reference Variability derived for ensatina, as extrapolated from vegetative conditions. Ensatina densities are assumed to be approximately 0.25 individuals per acre in these habitat types. The current and Reference Variability population sizes assume that all acres of these seral stages in Jeffrey pine and mixed conifer are suitable condition (i.e., sufficient canopy closure and other microclimatic determinants). For the purposes of this exercise, as long as the current estimates and Reference Variability estimates have the same bias, it is a legitimate estimator.

Since Reference Variability for this Indicator was derived indirectly, it would be important to identify this Indicator as a high priority for validation monitoring. Current population levels (or at least indices of them) need to be quantified and their habitat affiliations confirmed to validate the current population estimate, the Reference Variability estimate, and the population estimate for a viable population.

Recommended Management Variability should be coincident with the estimated number of individuals needed for a population that is expected to persist at a high level of probability (>80%) for at least the next 100 years.

Monitoring logs per acre is also a high priority, considering that the logs per acre in the seral stages and series identified is assumed to be at least 4-8 per acre over 10 " diameter. Management practices (past, current, or future) may reduce these levels below the Reference Variability. Ensatina populations and associated habitat features identified here are coarse-filter Indicators, and so serve to reflect the status of the ecosystem when considered in conjunction with other coarse-filter Indicators.

Aquatic Animal Species Element

The aquatic animal species Element had nine Indicators identified (Table B-1). One of those Indicators, the number and type of aquatic insect families in streams, will be discussed here. Reference Variability for aquatic insect families needs to be derived indirectly, since no data exist on the historic diversity of insect families within the area. Reference Variability for aquatic insects is based on the condition of the watersheds. The conditions and characteristics of the watersheds over the past 100-200 years prior is used as the reference period. The period is relatively short because insects have a short generation time, and therefore may have made recent adaptations such that longer time frames may not be appropriate for determining conditions that would conserve their diversity.

Many aquatic insect families are also useful Indicators of specific environmental conditions because they are sensitive to water quality and nutrient conditions. As such, insect families can serve as both biodiversity Indicators as well as water quality Indicators. Although the diversity of families is informative, it is even more informative to track the presence of individual families, since each family of aquatic insects has unique life history strategies and ecological niches.

Reference Variability is derived based on the presence of specific families of aquatic insects expected to exist in the area during the reference period. Table B-8 lists the families of interest and estimated occurrence both during the reference period and currently. Reference Variability is the presence of all

Table B-7. Reference Variability for seral stages of Jeffrey pine and mixed conifer vegetation series and their associated populations of ensatina.

Series	Seral Stage	Reference Variability (%)	RV[1] Acres	Ensatina Population RV	Current Ensatina Populations
Jeffrey pine	Mid Mature	2 - 23	400 - 4600	100 - 650	1150
(20,000 ac total)	Late Mature	2 - 12	400 - 2400	100 - 600	100
	Old Growth	33 - 53	6600 - 10600	1650 - 2650	1250
Mixed conifer	Mid Mature	2 - 29	600 - 8700	150 - 2175	1950
(30,000 ac total)	Late Mature	2 - 13	600 - 3900	150 - 975	100
	Old Growth	33 - 45	9600 - 13500	2400 - 10120	1850

[1] RV = Reference Variability

Indicator families, and Recommended Management Variability is the same set of families as for Reference Variability.

The diversity of families is also an important Indicator here, but deriving a Reference Variability for the diversity of all insect families is difficult. In this case, the relative diversity of specific families of interest is the only fairly reliable measure of change in diversity from the past to the present. It does not provide a measure of variability over time, but simply a presence or absence at some time in the past. These type of data may be the best possible data for many Indicators given the scarcity of historical data on the status of biota.

Overall diversity of aquatic insect families, and validation of the families of interest that are currently present need to be high priorities for monitoring. The overall diversity of families can be used to validate the current condition of streams and provide clues as to what management would conserve diversity within them. In addition, information on the relative abundance of families and their distributions will be useful data to collect in monitoring to assist in the interpretation of and management response to monitoring results.
The aquatic insect families Indicator is considered a coarse-filter Indicator here, and is therefore one measure of the status of the overall ecosystem.

Lifestyles and Lifeways Element

Eight primary Indicators were identified for this Element (Table B-1). Bear grass and sedge quantity, quality, access, and harvest experience were chosen for elaboration here. Bear grass and sedges are used for basket weaving by the Maidu and Miwok community members for hundreds of years.
The basketry material tending, gathering, and basket weaving have been important traditions in these communities. These activities are governed by a unique system of social mechanisms, political mechanisms and spiritual beliefs that serve to regulate resource use, distribute resources, and maintain the cultural landscape.

Native Americans have managed plants and landscapes to produce basket materials. Traditionally, the land is burned, and otherwise managed to create and maintain certain kinds of landscapes. They work within ecological cycles, and maintain the vigor and distribution of plants within the landscape. Plants are coppiced, pruned, and cultivated. The techniques and practices sometimes mimic nature, but are designed to encourage growth of long, pliable fibers.

Bear grass currently in use occupies 700 acres (in two patches) and sedges in use occupy 300 acres

Table B-8. Aquatic insect family Indicators.

Family	Common Name	Affiliation	Presence: Reference	Presence: Current
Baetidae	Mayflies	clean water	X	X
Corixidae	Water boatman	clean water	X	
Arctopsychinae	Caddisflies	cold, strong current	X	X
Simuliidae	Black flies	clean, fast water	X	X
Hydrophilidae	Water beetles	clean water	X	
Tabanidae	Deer flies	muddy water		X
Capniidae	Stone flies	clean water	X	
Elmidae	Riffle beetles	fast, oxygen	X	X

(in two patches) within the 100,000 acre area. There are five other known areas, two of bear grass and three of sedges, with the potential for future use.

Environmental Indicators were identified and defined by 1) consulting with knowledgeable traditional practitioners and tribal governments; 2) examining the archaeological record for paleoenvironmental data; and 3) conferring with researchers who are delineating the extent and character of environmental management by these cultural groups. Each of the chosen Environmental Indicators are described in greater detail below.

Quantity of Materials

The number of acres and plant density are the result of Miwok and Maidu historic and current weaver population needs for materials. Weaver populations levels have fluctuated over time, from 300 when tribal populations were at their peak, to a current population of 30. The acreage of bear grass and sedge peaked at about 5000 acres based on ethnographic and paleoenvironmental record. Active management maintained this high number of acres for some period of time. Under reduced intensities of management, some areas reverted to mixed conifer forest, reducing the acreage to a low of 500 acres. Currently, 1000 acres are sufficient to support the demand for materials. However, community interest is growing, and increased acreages may be needed to accommodate additional weavers over the next decade. The Reference Variability is 500 - 5000 acres, and the Recommended Management Variability should probably be 1000 - 2000 acres, based on existing populations and the potential for expanding demands.

Quantity of materials is affected by the density of plants within an area. Density is affected by management. Direct manipulation of the plants is discussed in the section addressing the quality of materials. The other major factor to consider in this location is the use of herbicides. Herbicides do not kill all the plants, but they affect plant density. Plant density in a healthy population of bear grass ranges from 100-200 plants per acre, and in sedges consists of 50-100% coverage of the area. These values represent the Reference Variability and Recommended Management Variability for bear grass and sedge densities.

Quality of Materials

The Miwok and Maidu consider the quality of basket weaving materials important. Generating the desired characteristics of plants needed for successful basket making requires direct and intensive manipulation of the plants. Manipulation of the plants typically includes burning, cultivation, pruning, coppicing, and harvesting at specified times during the year. Other considerations in the area include cattle grazing that tramples or pollutes plants, use of herbicides or pesticides, which may be health risks and trampling by recreationists. These activities in combination affect the following important features of the plants: length of the stems, flexibility, thickness of the stems, coloration, and potential health hazards.

Reference Variability is established for each of these plant features (Table B-9). Recommended Management Variability will be the same values as Reference Variability, since none of the values within the Reference Variability represent extremes that we would want to avoid as a result of management.

Access

Access is a concern to the Miwok and Maidu, since many of the weavers are older, and accessibility is important to ensure continuation of the tradition. The Forest Service controls access to all of the existing and potential gathering areas. Tertiary roads skirt two of the four existing gathering areas, and two other areas are accessible by trail. Access can be quantified in terms of average time required to reach the areas from a common access point (in this example they consist of the nearest paved highway), and the ability to use motorized or unmotorized transportation. The Reference Variability for time required to reach the areas (assuming trail access from the common access

point) probably ranged from 0.5 - 2.0 hours, depending on the season.

Recommended Management Variability for one bear grass and one sedge area is chosen to be 0.25 - 0.50 hours by unmotorized transportation; Recommended Management Variability for the other two areas is the same as Reference Variability. Remaining consistent with these Reference Variabilities and Recommended Management Variabilities will entail reviewing road maintenance schedules and road closure plans.

Harvest Experience

For the Miwok and Maidu, the harvest experience is a value and attitude Indicator. It could have been listed as associated with the attitudes, beliefs and values Element, and as such illustrates the connection that exists between many Elements. The harvest experience consists of the ability of those gathering the materials to experience the environment such that the rituals that coincide with gathering the materials can remain intact.

Before and during the harvest, the gatherers need peace and quiet free from visual intrusions, in order to focus on the significance of basket making in their own lives, the lives of their families, and the traditions of their community. The bear grass gathering areas should be in secluded areas.

A Reference Variability cannot be derived directly for the harvest experience. As for many cultural/social Indicators, there is a need to make a cross over from the cultural/social Indicator to some biological or physical indicator that we can develop a Recommended Management Variability to manage for. The Reference Variability for the harvest experience can be translated to the factors affecting the experience: development of access to the area, low noise levels, and limited visibility to and from highly developed areas. Reference Variability for all these factors is very low; and Recommended Management Variability is the same as Reference Variability for these factors.

Development in this area has fluctuated over time; Native American populations in the area were quite

Table B-9. Reference Variability for bear grass and sedge characteristics used in basket weaving.

Environmental Indicator	Bear Grass	Sedge
plant coverage/acre	>100 plants	50%
stem length	> 24 inches	> 12 inches
flexibility	highly pliable after soaking	highly pliable after soaking
thickness	0.5 - 1.0 mm	1.0 - 3.0 mm
coloration	light to golden brown when dry	golden brown when dry
health risks	none	none

high 500 years ago, then population levels decreased with the arrival of Euroamericans, resulting in a lower over all population density; and currently, population levels are at their highest ever (comprised of a diverse mix of ethnicities). In past times of higher population, noise levels per capita were lower, architecture blended with the surrounding landscape, and native materials were used for structures.

Reference Variability for visual concerns(i.e., limited visibility to and from highly developed areas) is described by a rating of the visibility from populated areas. The index ranges from 0-1.0, with four levels (0.0 = none, 0.3 = low, 0.6 = moderate, and 1.0 = high) defined by specific sets of conditions (Table B-10). Reference Variability and Recommended Management Variability are the same for this indicator, and is estimated to be 0.6-1.0. Bear grass and sedge use is a closed-system Indicator in this situation, and therefore is not being used as an overall indicator of ecosystem status. Instead, it is simply an Indicator of an important Ecosystem Element.

Next Steps

This example provides some detailed illustrations of how to accomplish the second and third steps of the analysis and planning process: deriving Reference Variability and Recommended Management Variability for Environmental Indicators (see Chapter 3). Once Reference Variability and Recommended Management Variability are derived for each Environmental Indicator, the remaining 11 steps of the analysis and planning process can be accomplished. The remaining 11 steps are:

- define desired condition
- determine the existing condition
- compare desired condition to existing condition
- identify opportunities
- list potential projects
- project selection, prioritization, and scheduling, Landscape Management Implementation Schedule
- NEPA disclosure and analysis
- line officer decision
- project implementation
- monitoring and feedback
- possible Forest Plan adjustment

These remaining 11 steps are not significantly different from our past analysis and planning processes, and therefore the detailed example ends here.

Table B-10. Visual index for the basket weavers experience.

Index	Rating	Definition
Visibility	0.0	Highly visible from populated areas; potential for interruption or harassment high
	0.3	Moderately visible from populated areas; potential for interruption or harassment moderate
	0.6	Low visibility from populated areas; potential for interruption or harassment low
	1.0	Not visible from populated areas; potential for interruption of harassment very low

Glossary

A

Abiotic - The nonliving material components of the environment, such as air, rocks, and water.

Adaptation - A characteristic that enhances an organism's chances for survival and reproduction.

Adaptive Management - Implementing policy decisions as an ongoing process that involves monitoring the results. It applies scientific principles and methods to monitor, then incrementally improve, resource management as managers and scientists learn from experience and from new scientific findings. Adaptation is also made as social changes and demands warrant.

Age class - An age interval, usually with a 10 to 20 year span, into which a vegetative area is classified.

Aquatic ecosystem - Any body of water, such as a stream, lake or estuary, and the living and nonliving components, all functioning as a system.

Aquifer - A water-bearing geologic formation or structure that transmits water in useful quantities.

Aspect - The compass direction toward which the slope of the land surface faces.

Association - Any assemblage of populations living in a defined area or physical habitat; as a loosely organized biotic unit it has characteristics additional to its individual species and population components (see "Biotic community").

Attitude - A feeling, disposition, or opinion; an element of the cultural/social dimension.

Autotrophs - Organisms capable of synthesizing organic matter from inorganic substances (e.g., green plants).

B

Belief - Conviction, faith, trust, etc.; an element of the cultural/social dimension.

Biocentric - Conservation strategies that focus on providing sufficient amounts and arrangements of habitats to maintain desired species. Also, a philosophical view emphasizing the maintenance of natural biological systems, disregarding commodity production and other human uses.

Biological dimension - Living elements of an ecosystem.

Biological diversity (biodiversity) - The distribution and abundance of different plant and animal species and communities within an area. Encompasses four levels: genetics, species, ecosystems, and landscapes.

Biological potential (biotic potential) - The maximum possible resource output limited only by inherent biological and physical factors. Also refers to the inherent ability of an organism to multiply in the absence of outside controlling factors.

Biomass - The total weight of one or more types of living organisms in some biological system.

Biome - A major biotic community composed of all the plants and animals and smaller biotic communities, including the successional stages of an area.

Biophysical - A term used to encompass all the naturally occurring biological (living) and physical (nonliving) objects and processes in an area.

Biotic community - See "Association"

C

Candidate species - A species being considered for listing by the federal government as threatened or endangered (see "Endangered species").

Canopy - The more or less continuous cover of leaves and branches formed by the crowns of adjacent trees or shrubs.

Canopy closure - The degree to which canopies obscure the sky or block the sun.

Capability - The potential of the land to produce goods and services under a set of management practices and at a given level of management intensity. Depends on site conditions (such as climate, soils, geology) as well as the application of management practices such as silviculture.

Carrying capacity - The specification of some level of use that will maintain the ability of the ecosystem to contain, absorb, or hold elements without major systemic change. Can be applied to biophysical, cultural, or ecological uses.

CASPO - The California Spotted Owl Environmental Assessment, which addresses the interim viability of the California spotted owl.

Catastrophic event - A large-scale, high-intensity natural disturbance that occurs infrequently.

Class I areas - An air quality designated for areas with the most stringent degree of protection by the Clean Air Act. Included are National Parks and wildernesses designated under the 1964 Wilderness Act. Class II, a lesser degree of protection, describes all areas not designated Class I.

Climax - The concept that there is a final, stable community in ecological succession, one that can reproduce itself indefinitely under prevailing conditions in the absence of disturbance (the concept itself is less accepted now than formerly).

Coarse filter - Characteristic of an ecological approach that focuses on entire communities of organisms, rather than on individual species.

Community - An aggregation of cultural or biological units having relationships that are mutual with the environment and with each other. Also, a second scale of the Cultural/Social Hierarchy.

Component - The kinds and numbers of organisms and physical attributes that make up the ecosystem -- the "pieces".

Conceptual Framework - Ecosystem management methodology for Region 5. Defines sustainability in terms of conserving biological and cultural/social diversity. Such diversity lowers the risk of creating conditions that threaten sustainability of ecosystems. The Conceptual Framework outlines a rationale and a process for sustaining ecosystems through the implementation of Land and Resource Management Plans.

Connectivity - Pertaining to a network of habitat patches linked by areas or corridors of like habitat; a measure of spatial contiguity within a landscape. It affects how organisms can move through the landscape.

Conservation - The careful protection, utilization and planned management of natural resources to prevent their depletion, exploitation, destruction, waste or neglect.

Constraint - An action which cannot be taken or which must be taken; a limitation.

Consumptive use - Use of a resource that reduces its supply.

Corridor - A linear strip of land managed for specific vegetational characteristics to allow the movement of wildlife between suitable habitat areas; the landscape elements that connect similar patches through a dissimilar matrix or an aggregation of dissimilar patches.

Cover - Vegetation used by wildlife for protection from predators (including humans) and from weather.

Cover type - A forest type now occupying the ground with no implication as to whether it is temporary or permanent (see "Forest cover type").

Critical habitat - Specific area occupied by threatened or endangered species, on which are found the physical and biological features essential to the conservation of the species.

Crown - The upper part of a tree or other woody plant carrying the main branch system and foliage above a more or less clean stem.

Cultural adaptation - The means by which people adjust, accommodate, or conform to changes within their environment; behavioral adaptations may be technological, organizational, or ideological.

Cultural diversity - The multiplicity of human customs, lifestyles, social organizations, and economies.

Cultural ecology - The spatial and temporal interrelationship of humans and their environment.

Cultural landscape - A geographic area, including natural and cultural resources, influenced by or reflecting human activity.

Cultural/social dimension - Those elements of ecosystems dealing with the origin, development, organization, and functioning of human societies and cultures.

Culture - Shared behavior learned by members of a society.

D

Decomposer - An organism, usually a bacterium or fungus, that breaks down the bodies or parts of dead plants and animals into simpler compounds.

Dependent species - A species for which a habitat element (e.g., snags) is deemed essential for the species to occur regularly or reproduce.

Desired condition - Land or resource conditions which are expected to result if planning goals and objectives are fully achieved. Formerly this was called "Desired Future Condition".

Diffusion - Spread of customs or practices from one group to another; an element of the cultural/social dimension.

Direct effect - An effect that occurs in generally the same time and place as the causal agent.

Dispersal - The movement of plants and animals away from their point of origin to another location where they subsequently become established and reproduce.

Disturbance - A discrete event, either natural or human induced, that causes a change in the condition of an ecological system.

Diversity - Physical, biological, or cultural variety.

Diversity index - A mathematical expression of the relative degree of habitat diversity per unit of area.

Dominant - A taxon or group of taxa (i.e., categories in a scientific classification system) which by their collective size, mass, or numbers exert the most influence on the other components of the ecosystem.

Drainage - A large area mostly bounded by ridges, encompassing part, most, or all of a watershed.

Durability - The ability of resources to tolerate sustained use without degradation of the quality or productivity of the resource base.

E

Ecocentric - A conservation strategy that focuses on providing habitat patterns that are manifestations of ecosystem processes operating at several scales.

Ecological approach - Natural resource planning and management that assures consideration of the relationships among all organisms, including humans, and their environment.

Ecological classification - A multifactor approach to categorizing and delineating, at different levels of resolution, areas of land and water having similar characteristic combinations of the physical environment (such as climate, geomorphic processes, geology, soil, and hydrologic function), biological communities (such as plants, animals, microorganisms, and potential natural communities), and the human dimension (such as social, economic, cultural, and the infrastructure). The Ecological Classification program in Region 5 reflects the ecological capabilities and limitations of sites.

Ecological process - The actions or events that link organisms, (including humans) and their environment -- such as disturbance, successional development, nutrient cycling, carbon sequestration, productivity, and decay.

Ecological site - A single specific location on the land that is representative of an ecological type. Serves as a reference or type location for ecological types.

Ecological status - The degree of similarity between the present community and the potential natural community on a site. Ecological status considers secondary succession for vegetation and the degree of similarity between existing soil conditions and soil conditions at the potential.

Ecological type - A category of land having a unique combination of potential natural community, soil, landscape features, climate, and differing from other ecological types in its ability to produce vegetation and respond to management. Categories of ecological types include all sites that have this unique combination of components with the defined range of properties.

Ecological unit - The map unit developed for an ecological type or types. A riparian ecological unit is a map unit developed for a riparian ecological type or types. This unit may include a complex of small and intricately associated ecological types too small to delineate separately.

Ecology - A branch of science concerned with the interrelationships of organisms and their cycles and rhythms, community development and environments -- especially as manifested by natural structure, interaction between different kinds of organisms, geographic distribution and population alterations.

Economics - The study of the production, distribution, and consumption of goods, services and wealth.

Ecoregion - A continuous geographic area over which the macroclimate and topography is sufficiently uniform to permit development of similar ecosystems on sites with similar properties. Ecoregions contain multiple landscapes with different spatial patterns of ecosystems.

Ecosystem - A system formed by the interaction of living organisms (including people) with their environment. Spatially, ecosystems are described for areas in which it is meaningful to talk about these relationships.

Ecosystem function - The flow of species, materials, and energy within an ecosystem, across landscapes and through time. Includes a variety of processes, such as succession, biotic food chains, fire, hydrologic systems, and nutrient cycling.

Ecosystem management - The skillful, integrated use of ecological knowledge at various scales to produce desired resource values, products, services, and conditions in ways that also sustain the diversity and productivity of ecosystems. This approach blends physical, biological, and cultural/social needs.

Ecosystem pattern - The structure that results from the distribution of organisms in, and their interaction with, their environment. Includes zonation, stratification, activity or periodicity, food-webs, reproductive patterns, social patterns, and stochastic patterns.

Ecotone - A transition between two or more biotic communities.

Ecotype - A locally adapted population of a species which has a distinctive limit of tolerance to environmental factors.

Edaphic - Pertaining to soil.

Edaphic climax - A climax determined largely by soil conditions.

Edge - Where plant communities meet or successional stages come together; the interface between landscape elements of different composition and structure.

Elements (of an ecosystem) - The basic building blocks of ecosystems. Three fundamental types of elements: **components** are the kinds and numbers of organisms and physical attributes that make up the ecosystem -- the "pieces"; **structures** refer to spatial distribution or pattern of these "pieces"; and **processes** refer to the flow or cycling of energy, materials, and nutrients through space and time.

Empirical - Derived from direct observation or experimentation.

Endangered species - Any species in danger of extinction throughout all or most of its range, as defined in the Endangered Species Act.

Endemic - A taxonomic category of organisms whose natural occurrence is confined to a certain region and whose distribution is relatively limited.

Environmental Indicator - A quantitative measure of an ecosystem element which is used to describe the condition of an ecosystem; they are measures that change over relatively short periods of time and are affected by management.

Erosion - The detachment and movement of soil from the land by wind, water or gravity.

Eutrophication - The process of overfertilization of a body of water by nutrients that produce more organic matter than the self-purification processes can overcome.

Exotic species - Any species that is not indigenous, native or naturalized.

F

Fine filter - Characteristic of an approach that focuses on conserving individual species, rather than on entire communities of organisms.

Fine organic matter - All plant litter, duff, and woody material less than 3 inches in diameter.

Fire regime - The characteristic frequency, extent, intensity, severity and seasonality of fires in an ecosystem.

Fluvial - Of or pertaining to streams and flowing waters.

Food chain - A series of spatially associated species, each of which lives as a predator, parasite or absorber of the next lower species in the sequence.

Food web - All the food chains and interconnections between food chains in the biotic community.

Forage - All browse and herbaceous plants that are available to feed livestock or wildlife.

Forb - Any herbaceous plant other than grasses or grasslike plants.

Forest cover type - A category of forest defined by plant species composition, age and structure.

Forest Plan - Source of management direction for an individual National Forest or Grassland, specifying allowable activities, minimum requirements, expected outputs and land use allocations for a ten- to fifteen-year period.

Forest structure - Often divided into four conceptual aspects: age, species composition, horizontal (mosaic) pattern, and vertical (i.e., single or multiple stories).

Forest type - A way to group stands of similar character of development and species composition by which they might be differentiated from other groups of stands.

Fragile - Those land or water areas containing ecosystems that are sensitive to external stimuli which may disturb their balance, especially in an irreversible direction.

Fragmentation - The process of reducing the size and connectivity of forested stands that comprise a forest; a measure of connectivity in vegetative conditions across a landscape.

Fuels - Any material capable of sustaining a fire; usually live or dead natural material.

Function - The specific role or activity of an ecosystem component. For example, fire functions as a rapid decomposer of woody material (see "Process").

Functional planning - Planning which focuses on a single aspect or resource of a total complex.

G

Gap analysis - Process to determine distribution and status of biological diversity and assess adequacy of existing management areas to protect biological diversity.

Gene pool - All of the genes present in a population.

Genotype - The genetic constitution of an organism, as distinguished from its physical appearance which is the result of both heredity and environment.

Geographic Information System - A computerized mapping system that can store, display, analyze and report on information that is tied to geographic locations.

Goal - A concise statement that describes a desired condition to be achieved some time in the future. Goals are normally expressed in broad, general terms and may or may not have a specific date for accomplishment.

Grain - Pertaining to landscapes, the average size of landscape elements; these result in an overall landscape "texture".

Guideline - An indication or outline of policy or conduct that is not mandatory (as opposed to a "standard", which is mandatory).

Guild - A group of organisms that share a common resource.

H

Habitat - The natural environment of a plant or animal.

Habitat type - The aggregate of all areas that support or can support the same plants and animals.

Healthy ecosystems - Normally, an ecosystem in which structure and functions allow the maintenance of biological diversity, biotic integrity, and ecological processes over time. The term is laden with values that have not been consistently defined, and is not used in this text.

Herb - Any flowering plant except those developing persistent woody stems above ground.

Heterotrophs - Organisms which use the complex substances produced by autotrophs as a food base, and ingest or decompose them.

Hierarchical - A nested classification approach where lower level units aggregate into higher level units.

Homeostasis - The tendency of a system to maintain internal stability through the coordinated response of its parts to changing conditions.

Home range - The area in which an animal conducts its activities during a defined period of time.

Hydrologic function - The inherent capacity of a soil to intake, retain, and transmit water

Hydrophyte - Plants typically found in wet habitats.

Hygric (hydric) - Wet or moist environmental conditions, distinguished from "mesic" (moderate) and "xeric" (dry).

I

Implementation schedules - Schedules of projects and specific actions to implement a Land and Resource Management Plan (Forest Plan), including site-specific actions, responsibilities, and target dates.

Indicator - An organism or an ecologic community that is so strictly associated with a particular environmental conditions, that its presence (or absence) is a fairly certain sign or symptom of the existence of these conditions (see "Environmental Indicator").

Indigenous species - Any species of flora or fauna that naturally occurs in an area and that was not introduced by humans; synonymous with "native species".

Indirect effect - Those effects occurring at a later time or at some distance from the triggering action.

Individual - Single, separate thing or being; the smallest scale of Cultural/Social Hierarchy.

Infrastructure - The foundation or network (transportation, communications, schools, utilities, etc.) underlying an area's social structure.

Insolation - The amount of solar heat and light effectively reaching the ground.

Instream flow - A prescribed level of streamflow, usually expressed as a stipulation in a permit or license authorizing a dam or water diversion, to meet resource (riparian, fisheries, visual, etc.) objectives.

Intermittent stream - A stream which in general flows during wet seasons and is dry otherwise.

Invention - Discovery of a new tool or principle that becomes socially shared; an element of the cultural/social dimension.

L

Land unit - The smallest scale in the Terrestrial Hierarchy.

Land use allocation - The committing of a given area of land or resources to one use, or specific uses (e.g., campgrounds, wilderness).

Land use pattern - The relationships and context of human uses of landscapes; an element of the cultural/social dimension.

Landform - Used to describe the many types of land surfaces that result from geological processes: plateaus, plains, basins, mountains, etc.

Landscape - An area of interacting ecosystems where patterns are repeated because of geology, landform, soils, climate, biota, and human influences throughout the area. The size, shape, and patterns of landscapes are determined by interacting ecosystems.

Landscape ecology - The body of knowledge pertaining to the ecological effects of spatial patterns in ecosystems.

Landscape heterogeneity - Variation in aggregations of landscape elements across a landscape.

Landscape Management Implementation Schedules - A planning schedule that documents existing conditions, desired conditions, and projects that will achieve desired conditions.

Late successional forests - Forest seral stages that include mature and old-growth age classes.

Lentic - Pertaining to, or living in, still waters -- as in lakes, ponds and swamps. Contrasts with "Lotic" -- living in actively moving waters.

Lifestyle - Habits, attitudes, tastes, standards that together constitute mode of living; an element of the cultural/social dimension.

Lifeway - Subsistence, economic and other behavior patterns that together constitute a way of living; an element of the cultural/social dimension.

Limiting factor - Any environmental factor whose presence, absence, or abundance is the main factor restricting the distribution, numbers, or condition of an organism.

Linkages - Routes that permit movement of plants and animals from one habitat to another.

Lotic - Relating to, or living in, actively moving waters, such as streams, rivers, and waves. Contrasts with "Lentic" -- living in still waters.

M

Management area - A Forest Planning term denoting a contiguous area of land to which one or more management prescriptions are applied. Each management area is allocated to one or more management prescriptions.

Management direction - The aggregate of a Forest Plan's goals and objectives, standards and guidelines, management prescriptions and management area direction.

Management indicator species - A wildlife species whose population status and trend in a certain habitat type indicates the population and trend of other species that depend on the same habitat.

Management practice - A specific activity, measure, course of action, or treatment.

Management prescription - A composite of specific multiple-use direction applicable to one or more areas described in a Forest Plan; generally includes, but is not limited to, goals, objectives, standards, and guidelines and possible management practices that are allowed.

Matrix - Pertaining to landscapes, the matrix is the most connected portion of the landscape; that is, the vegetation type that is most contiguous.

Mean fire interval - Arithmetic average of all fire intervals, determined in years, in a defined area during a specified time period.

Mesic - Environmental conditions that have medium moisture supplies, as opposed to hygric (wet) or xeric (dry).

Microclimate - The local climate of a given site or habitat varying in size from a tiny crevice to a large land area, but being usually characterized by considerable uniformity of climate over the site. Microclimates are relatively local compared to enveloping macroclimates, from which they differ because of local conditions, such as exposure.

Microhabitat - A restricted set of distinctive environmental conditions that constitute a small habitat, such as the area under a log.

Microsite - A rock outcrop, snag, seep, stream pool or other environmental feature that is small in scale but unique in character.

Milankovitch Cycle - A 100,000 year climatic cycle of global warming and cooling.

Mitigate - Actions to avoid, minimize, reduce, eliminate, or rectify the adverse impact of a management practice.

Model - An idealized representation of reality for purposes of describing, analyzing, or understanding some aspect of it.

Monitoring - The collection of information to determine the effects of resource management and to identify changing resource conditions or needs.

Multi-layered, multi-storied - Terms applied to forest stands that contain trees of varying heights and diameter classes and therefore support foliage at various heights in the vertical profile of the stand.

Mutualism - A relationship between two species of organisms in which both benefit from the association.

N

National Environmental Policy Act - Legislation declaring the productive harmony with nature, and protection of the environment, to be a national policy.

National Forest Management Act - Legislation directing, among other things, the preparation of Land and Resource Management Plans for each unit of the National Forest System.

Naturalized species - Any non-indigenous species of flora or fauna that is close genetically or resembles an indigenous species and that has become established in the ecosystem as if it were a native.

New Perspectives - A Forest Service philosophy originated in the late 1980's to bring about new thinking, new technologies and new alliances to improve ecological management of the National Forest System.

Niche - A site or habitat supplying the factors characteristically necessary for the successful existence of an organism or species.

Nonconsumptive use - Use of a resource in a fashion that does not reduce its supply.

Nondegradation - The policy of not allowing resources to deteriorate any further than what exists at a chosen point in time. The objective is to either maintain the status quo, or to improve resource conditions.

Nuclear family - Family unit that consists of parents and dependent children or adults, or some combination thereof.

Nutrient cycle - The circulation of chemical elements, such as carbon or nitrogen, in specific pathways from the abiotic parts of the environment into the organic substances (plants and animals), and then back again into abiotic forms.

O

Objective - A clear, specific statement of planned results to be achieved within a stated time period. The results indicated in the statement of objectives are those designed to achieve an overall goal.

Old growth - Ecosystems distinguished by old trees and their related structures. Old growth encompasses the later stages of stand development that typically differ from earlier stages in larger tree size, higher accumulation of dead, woody material, multiple canopy layers and different species composition.

Output - A broad term for describing any result, product or service produced by a process or activity.

Overstory - Those trees in a forest that form the uppermost layer of canopy.

P

Parent material - The unconsolidated and more or less chemically weathered, mineral or organic matter from which soils develop.

Patch - A small (20-60 acre) part of the forest; an area of vegetation that is internally homogeneous, differing from the matrix that surrounds it.

Perennial stream - A stream that flows throughout the year.

Phreatophyte - A type of plant that habitually obtains its water from the zone of groundwater saturation.

Physical dimension - The nonorganic, abiotic elements of ecosystems.

Physiographic - The description of the surface features of the earth, as bodies of air, land and water.

Physiographic province - A region having a particular pattern of relief features or landforms. The pattern differs significantly from that of adjacent regions.

Plant association - A potential natural plant community of specific floristic composition and appearance.

Plant community - An aggregation of plants similar in species composition and structure, occupying similar habitats over the landscape (see "Community").

Pollution - The presence of matter or energy whose nature, location or quantity produces undesired environmental effects.

Population dynamics - The aggregate changes that occur within a population over time. Included are all phases of recruitment, growth, senility, mortality, seasonal fluctuation in biomass, and persistence of each year class and its relative dominance.

Potential natural community - The biotic community that would be established if all successional sequences of its ecosystem were completed without additional human-caused disturbance under present environmental conditions. Grazing by native fauna, natural disturbances, such as drought, floods, wildfire, insects; and disease, are inherent in the development of potential natural communities, which may also contain naturalized nonnative species.

Prescribed fire (prescribed burn) - A wildland fire ignited by humans under specified conditions, to accomplish specific, planned resource objectives. This practice, common in California, is also known as "controlled burning".

Prescribed natural fire - A wildland fire ignited by natural causes such as lightning or vulcanism. These are "prescribed" only in the sense that they are allowed to burn in designated areas under conditions carefully planned to provide for safety and control of the fire.

Prescription - A written statement outlining the means to achieve predetermined objectives. For example, a fire prescription would describe an acceptable range of conditions (such as temperature, humidity, windspeed, and fuel moisture).

Primary succession - Vegetative development that begins on newly-formed soils or upon surfaces exposed for the first time (as by landslides).

Process - A series of action, changes, or functions that achieve an end or result (see "Ecological process").

Productivity - Characteristic that enables an area to provide goods and services and to sustain ecological values.

Province - See "Physiographic province".

R

Range - All land producing naturalized or native forage for animal consumption; generally, range is not cultivated.

Reach - A continuous, unbroken stretch of a stream with homogeneous characteristics.

Recommended Management Variability - Potentially a subset of Reference Variability for an Environmental Indicator; defines conditions that may omit extremes that would prejudice the attainment of desired conditions.

Recovery - The achievement of viable populations of threatened or endangered species.

Recruitment - The addition to a population from all causes, including reproduction, immigration, and stocking.

Reference area - Places where disturbance regimes and ecological processes have been minimally changed over the past 100-200 years.

Reference Variability - The spectrum of conditions possible in ecosystem composition, structure, and function, considering both temporal and spatial factors. Specifically, it is the distribution of data values for an Environmental Indicator over a selected period of time (for biological Indicators, an evolutionary time period). Also referred to as Natural Range of Variability or Historic Range of Variability.

Refugia - A relatively isolated and/or uncommon areas or habitat for organisms that are habitat specialists.

Region - A broad geographical or cultural area or range of some specified interest; the largest scale of Cultural/Social Hierarchy.

Relict - A biotic community or species which has survived some major environmental change that has altered the vegetation of surrounding community. Survival is made possible by some protective or compensating feature.

Research Natural Area - An area established specifically to preserve a representative sample of an ecological community for scientific and educational purposes.

Resident fish - Fish that are not migratory and complete their life cycle in fresh water.

Resilience - The ability of an ecosystem to maintain diversity, integrity, and ecological processes following disturbance. An ecosystem well supplied with species adapted to disturbance will typically be resilient.

Riparian (area or zone) - The land and vegetation immediately adjacent to a body of water, such as a stream, lake, river, or estuary; such vegetation depends upon a perpetual source of water.

Riparian ecosystem - An ecosystem transitional between terrestrial and aquatic ecosystems.

S

Saprobe - An organism deriving its nourishment from nonliving or decaying organic matter.

Scale - The degree of resolution used in observing and measuring ecosystem processes, structures and changes over space and time.

Seasonal round - Subsistence pattern characterized by movement from one location to another on a seasonal basis to take advantage of availability of varying resources.

Secondary succession - The concept in which a sequence of vegetational reestablishment occurs on soils that bore vegetation prior to a disruption of the normal successional process.

Sense of place - An attachment to specific landscapes or sites reflecting attitudes, beliefs, and values within the cultural/social dimension.

Sensitive species - Species designated by the Regional Forester as needing special management to prevent them from becoming threatened or endangered.

Seral stage - A biological community viewed as a single developmental or transitional stage in an ecological succession.

Sere - The series of successional stages of a biological community.

Series - An aggregation of taxonomically related plant associations which take the name of (climatic) climax species that dominate, or have the potential to dominate, the principal vegetative layer in a time frame appropriate to the vegetative or taxonomic group under consideration.

Settlement pattern - The relationships and context of human occupations of landscapes; an element of the Cultural/Social dimension.

Shrub and tree cover - The amount of soil covered by the canopies of shrubs and trees.

Small group - A minimal aggregation of individuals; the smallest scale of Cultural/Social Hierarchy.

Snag - A standing dead tree.

Social organization - The structure, relationships, and networks for cultures and societies; manifests itself in institutions, community, and legal constructs; an element of the cultural/social dimension.

Society - A group of people who share the same cultural traditions.

Soil - The unconsolidated mineral and organic matter on the surface of the earth that has been subjected to and influenced by genetic and environmental factors of parent material, climate (including moisture and temperature effects), macro- and microorganisms, and topography. These all act over time to produce soil, which differs from the material it is derived from in many physical, chemical, biological, and morphological properties and characteristics.

Soil cover - The amount of surface area covered by low-growing vegetation (grasses, forbs, and prostrate shrubs), plant litter and debris, and surface rock fragments larger than about 3/4 inches.

Soil drainage classes - Used to evaluate the effect of management-induced water table of subsurface flow changes on plant growth or potential plant community composition.

Soil hydrologic function - The inherent capacity of a soil to intake, retain, and transmit water.

Soil moisture regime - Refers to the presence or absence of either ground water held at a tension of 1500 kPa in the soil or in specific horizons by periods of the year.

Soil organic matter - The organic fraction of soils, exclusive of undecayed plant and animal residues.

Soil porosity - The volume of pores in a soil sample (non-solid volume) divided by the bulk volume of the sample.

Soil productivity - The capacity of a soil to produce biomass through plant growth.

Soil survey - The systematic examination of soils in the field and laboratory, including description, classification, interpretation of productivity, and mapping.

Species - A fundamental category of plant or animal classification.

Species richness - The number of species, either in total or by some grouping scheme.

Stability - The concept in which all niches are occupied by appropriate species and no species becomes extinct.

Stand - A community of trees or other vegetation that is sufficiently uniform in composition, age, spatial arrangement, and condition to be distinguished from adjacent communities; thus, it forms a management entity.

Standard - A specified level of attainment or acceptability, usually expressed in quantifiable terms; used as a rule to measure against.

Stochastic - Random or uncertain variation.

Stratification - The process of aggregating areas with similar resource conditions into broad categories for sampling and analysis purposes.

Stress - A force that pushes the functioning of a critical ecological system beyond its ability to resist or recover.

Structure - The patterns of association (vertical, horizontal, or temporal) among ecosystem elements.

Subclimax - The concept in which a biological community has ceased successional development short of its potential ecological climax because of inhibition by some environmental factor other than climate.

Subregion - One of the scales in the Terrestrial Hierarchy; often used in Resource Planning Act assessments and statewide planning; encompasses hundreds to thousands of square miles. Also a scale in the Cultural/Social Hierarchy; a geographical or cultural area or range of some specified interest; aggregates of communities and cultural landscapes.

Subseries - An aggregation of taxonomically related plant associations within a series that takes the name of that series followed by related species that are dominant, or have indicator value across multiple plant associations.

Subsistence - Basic economic pattern providing sustenance and support; an element of the cultural/social dimension.

Subsistence cycle - See "Seasonal round".

Succession - The predictable, orderly, long-term developmental changes of an ecosystem, involving changes in species composition, structure, and community processes (see "Primary succession" and "Secondary succession").

Suitability - The appropriateness of applying certain management practices to a particular area of land. This is determined by an analysis of the economic and environmental consequences and the opportunity cost of uses foregone.

Suitable habitat - The biological and physical components necessary to meet some or all of the needs of a species.

Sustainability - The ability to maintain diversity, productivity, resilience to stress, health, renewability, and yields of desired values, resource uses, products, or services over time in an ecosystem while maintaining its integrity.

Sustainable development - The use of land and water to sustain production indefinitely without environmental degradation, ideally without loss of native biodiversity.

Sustainable ecosystem management - Management directed towards developing or maintaining a synergistic complex of plants, animals, and cultural components that can perpetuate itself (or be perpetuated) indefinitely.

Sustainable yield - The perpetual output of a renewable resource, achieved and maintained at a given management intensity, without impairment of the productivity of the land.

Synecology - The relationship of organisms and populations to biotic factors in the environment.

Synergism - Takes place when combined action of two or more agents is greater than the sum of the individual actions.

T

Taxon - A category in a scientific classification system.

Taxonomy - The science of classification of organisms; the arrangement of organisms into systematic groups, such as species, genus, family, etc.

Temporal - Relating to time.

Terrain - The physical features of a tract of land.

Terrestrial ecosystem - Communities that are not dependent upon a perpetual source of water; a land-based ecosystem.

Threatened species - Those plant or animal species likely to become endangered throughout all or a significant part of their range within the foreseeable future, as defined in the Endangered Species Act.

Threshold - The minimum concentration or amount of a given substance or condition necessary to produce a measurable effect.

Trophic level - Organisms whose food is obtained from the same general source (e.g., plants fed by sunlight and soil, animals that feed on plants, animals that feed on other animals); nutrient level.

Type conversion - The conversion of one vegetation type or plant species to another, such as shrub to grass.

U

Understory - The trees and other woody species growing under a more or less continuous cover of branches and foliage formed collectively by the upper portions of adjacent trees.

V

Value - Relative worth, merit, importance, desirable quality, or ideals; an element of the cultural/social dimension.

Varves - Lake sediments deposited under quiet conditions that form annual layers; used for dating.

Vegetation type - A plant community with distinguishable characteristics (see "Cover type").

Viewshed - An expansive landscape or panoramic vista seen from a specific viewpoint, such as from a road.

Visual or scenic quality - Scenic attributes of landscapes that elicit psychological and physiological benefits to humans.

W

Watershed - The entire area that contributes water to a drainage system or stream. Portion of the forest in which all surface waters drain to a common point.

Watershed Analysis - An analysis approach that considers biological, physical, and cultural/social dimensions, but which is not identical to the Conceptual Framework. Its analysis scale is confined to one level, and focuses on specific issues. The watershed and river basin scales are recognized nationally as scales at which many important ecosystem elements can be described and analyzed (e.g., FEMAT, PacFish).

Wetlands - Areas that are inundated by surface or ground water with a frequency sufficient to support a prevalence of vegetative or aquatic life dependent upon the water for growth and reproduction.

Wilderness - Areas designated by Congress that are managed, in the words of the Wilderness Act, "for primeval characteristics, solitude, or unconfined primitive recreation, natural conditions, and where the imprint of man is substantially unnoticeable."

Woodland - An ecosystem characterized by an open forest cover type, in conjunction with another vegetation type, such as grassland or shrubland.

X

Xeric - Refers to a habitat characterized by dry conditions.

Z

Zoning - The demarcation of a planning area into zones, which the establishment of regulations to govern the types of activities and uses within each zone.

Index

GPO 683-099/11046